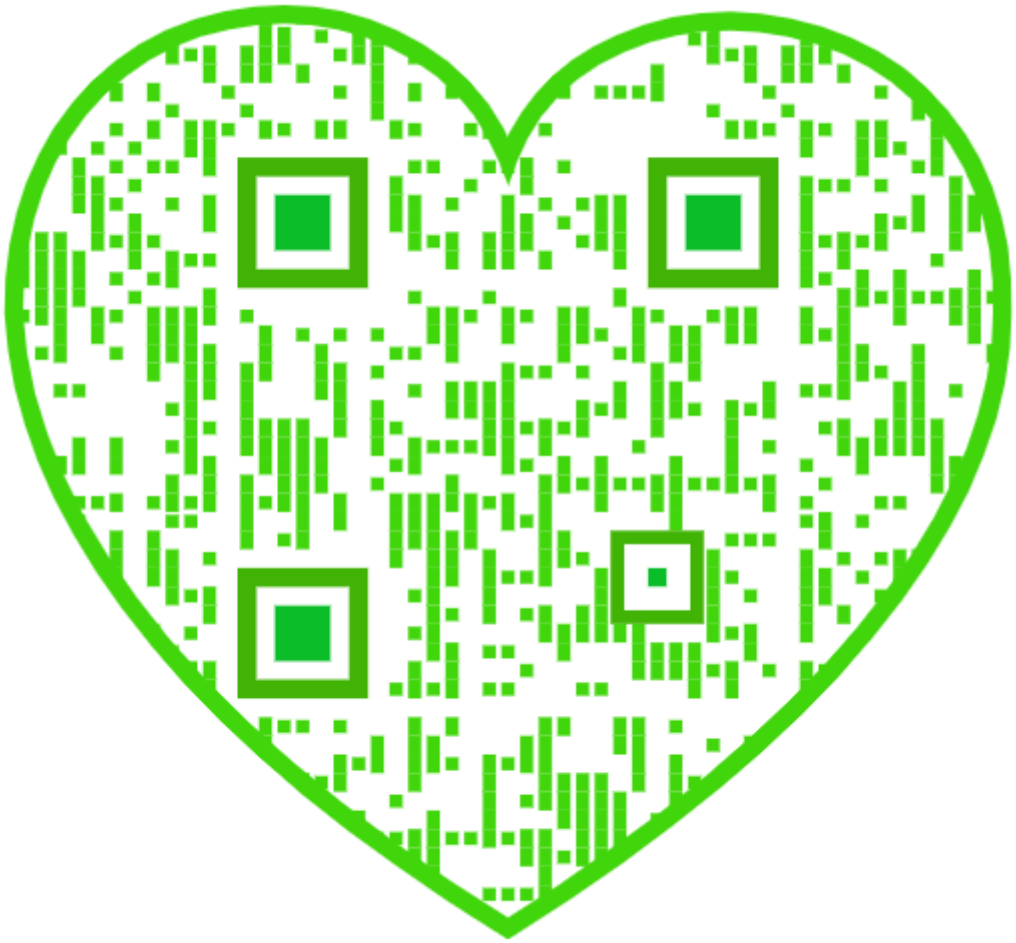

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OBSERVATIONS ON POTATO PROBLEMS IN UNITED STATES[1]

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Through this article I wish to express appreciation for kindly and courteous treatment received at the hands of many people connected with the potato industry, during a coast-to-coast trip through large commercial potato areas in the United States this year.

I had the privilege of calling on several hundred prominent growers, dealers, brokers, departmental and college officials, many of whom expressed the hope of making a similar trip some time. Noting everywhere a general desire for information concerning problems confronting the industry in [illegible] iat members of the Potato Association of Am[illegible] in some of the observations recorded, particul[illegible] read this article materially helped to provide th[illegible]

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Starting early in January [illegible] rip extended to nearly one hundred potato growing and marketing centers in thirty-five States, and was completed by the end of June. The order in which the States were visited is as follows: New York (City and Long Island), New Jersey, Pennsylvania, Maryland, Washington, D. C., Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Louisiana, Arkansas, Tennessee, West Virginia, New York (West), Ohio, Kentucky, Missouri, Kansas, Colorado, Wyoming, Utah, Cali-

[1]Contribution No. 22 from the Plant Protection Division, Production Service, Department of Agriculture, Ottawa, Canada.

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fornia, Oregon, Washington, Idaho, Montana, North Dakota, Minnesota, Iowa, Nebraska, Wisconsin, Illinois, Indiana, Michigan.

The objects were to ascertain for our information and guidance (1) if Canadian seed potatoes, where used, were giving the satisfaction desired; (2) the trend in the use of new varieties; (3) the attitude toward southern tests for northern-grown seed; (4) the effectiveness of Florida tests; (5) the attitude and trend toward washing and brushing potatoes; (6) environmental effects on new varieties; (7) progress in Bacterial Ring Rot control; (8) irrigation practices in potato production; (9) attitude toward tuber-indexing and tuber unit work as a means of improving seed stocks; (10) information on low-cost disinfectants; (11) other relevant and useful information to improve quality in seed potatoes; in short, discussing problems of seed potato certification for mutual benefit.

Obviously, the space available will not permit a detailed report covering so much ground, and in any case it is only intended to summarize briefly the impressions secured as a result of discussions with specialists in their own home locations. Credit for information provided can also only be acknowledged in a general way here but gratitude for this aid freely given is none the less sincere.

For brevity the observations are recorded in paragraphs under various headings.

NEW VARIETIES. THE CHIPPEWA is giving excellent yields in many northern districts and at suitable altitudes in other areas. This variety is reported to be especially profitable in muckland soil for washed potato trade, and a premium is paid for its attractive appearance. Apparently the Chippewa is not doing well south of New Jersey. The following criticisms were made—considered a tender variety where storage or growing conditions are below average—sprouts too soon in normal storage and is subject to discoloration in cold storage; sunscalds easily, and breakdown in transit rapid—susceptibility to leaf roll may limit wider use. The HOUMA is doing well in northern districts on account of good table and yielding qualities. Other areas report too numerous tuber set for sizing. Houma, Louisiana, after which it was named, has discontinued its use due to its susceptibility to Early Blight under local conditions. The KATAHDIN continues to increase in production and over a wider area. It has yielded well under drought and other adverse conditions and has displaced rurals in many areas. Its susceptibility to common scab and hollow heart alone

limits its wider use in some districts. It was reported that SEBAGO production is increasing in northern districts where yielding qualities are very good, but other districts find it too late maturing for their purpose. It has established good resistance to late blight in the north, but it is quite susceptible to that disease in southern Florida, probably because of the reduced photoperiod. The SEQUOIA is doing very well in many test plots. It will undoubtedly receive much wider distribution when its leaf hopper and flea beetle resistant qualities become better known, and supplies of good seed have been built up. It is more resistant to late blight than many varieties. It is a long season variety and suitable only for the late market. The PONTIAC is a red variety of excellent yielding and table qualities. It was released to compete with Bliss Triumph, but is somewhat later and is not a very popular potato on the markets. Foliage type is difficult to read for mosaic. Will probably not continue very long in production. The WARBA appears more suitable for market gardeners than for large-scale production. It is a very early high-yielding variety of good cooking quality, but its deep and pink colored eyes are discriminated against when other sorts are available. The RED WARBA, a mutation from Warba, is giving excellent results in middle-west tests. It has good yielding qualities but breaks occasionally to splashes of white. It will probably continue with limited distribution. The EARLAINE is not widely known and its value appears uncertain at this time. It will not displace the Irish Cobbler. It has given good results in some districts but does not appear to be consistently good.

SOUTHERN TESTS FOR NORTHERN GROWN SEED. This refers to the planting of samples in southern states during the winter. The samples are drawn from various lots of certified seed grown in the northern states. The idea is to ascertain by this sample the percentage of disease present in individual lots of seed, and is intended as a check on a grower's crop to determine if much disease had been acquired after the final field inspections. The demand for this service has developed partly as a result of delivery of poor seed to table stock growers, and partly by certification services in an effort to provide more reliable seed to the potato industry.

To summarize the interviews held on this subject, it would

still seem that there is not yet a great demand for the service on the part of seed purchasers. The principal requests came from Long Island growers' organizations who are urging a southern plot check on all seed intended for sale in that area. Very few of the seed importers elsewhere showed much interest in the plan. The general opinion appeared to be that if samples are sent south for the purpose of securing readings with a view to refusing further field inspections on poor lots, then the idea was excellent, but if samples are sent to secure good readings on which to sell crops during the current season then the risk of manipulation of seed samples rendered the readings of doubtful value. There also appeared to be some uncertainty about the value of readings of some diseases especially with some varieties under the southern environmental conditions. Some of the Long Island concerns have recently deemed it expedient and necessary to acquire greenhouse space to further check on readings by tuber-index methods, and it is expected this phase of the tests may be enlarged in the future. However, it can definitely be said for the certification officials who conduct the work and really put a lot of time and effort into the program that they feel the value of the tests far exceeds the costs incurred, amounting to about $100 per acre of southern plots.

Another phase of southern tests is that laid down by one or two of the Agricultural Departments in the south. In Alabama, for instance, a state that imports large quantities of seed potatoes, they test seed potato samples without charge from stocks which will be grown elsewhere during the current season, but the progeny of which is intended for sale as seed in Alabama. If the sample yields come within 75 per cent of the 10 highest yielding lots in the plots, then all properly graded potatoes grown from seed represented by sample is eligible for recommendation by the state, and official tags may be stamped "Tested and Approved in Alabama." The cost of this test plot work at Fairhope, Alabama, and which now covers the growing of approximately 50 acres of plots, is paid by the state to encourage the planting of good yielding lots of certified seed, and to discourage the sale of so-called "Selected Seed" within the state. Incidentally, information secured indicated that some other states are considering ways and means of discouraging the sale of uncertified potatoes as seed.

WASHING AND BRUSHING POTATOES. Indications point to this practice becoming more general in spite of the fact that it has

been discontinued by some shippers who found that the added cost exceeded the premium received. The fact that more sidings and warehouses are being equipped with washers, and the spread in price between washed and unwashed potatoes appears to be widening in many of the larger markets, is evidence of this trend. Unfortunately, the spread appears to be widening more at the expense of unwashed potatoes than in a rising price level for washed, which means that the producer appears to be well on the way to assuming the added burden at no profit. Added to the cost of washing is that of drying which requires expensive machinery in some districts. The loss from breakdown, due to rots actually resulting from washing and drying have been remarkably small, but it is agreed that washed potatoes should always be marketed and consumed promptly, and not held for storage purposes. Brushing without washing is on the increase in some districts, but has been discontinued in others. Potatoes for brushing must be quite dry; if they are not, they may appear dirtier than before. Potatoes intended for seed should not be put through a brusher if potatoes affected with ring rot have previously been cleaned in the machine.

TUBER INDEXING. After hearing dubious remarks from one source about the value of tuber-indexing, it was a most pleasant surprise to find unanimity of opinion among those actually engaged in the work throughout the country that tuber indexing is of definite value, and is highly recommended as a means of improving and maintaining quality of seed stocks. It was agreed that the method was not perfect because some tubers which pass as indexed later proved diseased, but that point is insignificant compared with the value of locating disease in seed stocks more easily by tuber indexing than can be accomplished in the field. Tuber indexing in conjunction with tuber unit seed plot work conducted under proper isolation is what the industry may eventually have to depend upon to maintain all seed stocks to present high standards. The number of glasshouses in use, under construction, or being provided for throughout the country, and intended for potato tuber-indexing is some further indication of its merit.

BACTERIAL RING ROT CONTROL. There is no doubt about Bacterial Ring Rot having spread far and wide throughout the country during the past few years, and that all concerned are taking more interest in the situation. One encouraging feature, it is

agreed, is that where diseased stocks are completely disposed of, proper sanitary measures taken, and new disease-free seed planted, all chances are in favor of complete control on that property. Another is seen in the extraordinary measures taken by some prominent growers and officials to keep the disease out of their seed stocks. In some cases smears are taken from every tuber intended for seed plots or are examined under an ultra violet light before indexing. The tubers are distributed to selected farms to grow in units by tuber lines for multiplication. The seed produced in this way may form the nucleus for foundation seed produced in various distant parts of the country.

A final decision about the value of the ultra violet light for Bacterial Ring Rot identification, compared with the smear method, is reserved by some operators, but has been fully accepted as satisfactory by others who have specialized in the ultra violet light work. However, it is the usual practice to check all doubtful material by smears. It would seem that a combination of the two, speeds up the work very materially and appears effective in the hands of operators experienced in the use of ultra violet light.

In conclusion it might be said that a more enthusiastic group than those found in the field of seed potato production and pest control in the U.S.A. would be difficult to find. The industry, generally speaking, is not so prosperous as it should be. The whole trade is highly competitive and is working on margins that are far too slim, but prospects appear to indicate somewhat better conditions for the future. Let us hope this may be so.

WEED SUSCEPTS OF THE POTATO YELLOW DWARF VIRUS

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The proximity of clover fields to potato fields was correlated with an increase in the incidence of yellow dwarf of potatoes by Black (1), and Mader (5). This association was not observed by Walker and Larson (6) in some Wisconsin areas. Recently, Hansing (4) reported the spread of the yellow dwarf virus in New York within small areas

*The writer wishes to acknowledge the helpful suggestions and criticisms of Dr. F. M. Blodgett.

where clover was not prevalent. He suggested that weed suscepts might be as important as clovers in overwintering and maintaining a source of the virus. Hansing (4) demonstrated that the weeds, *Barbarea vulgaris* R. Br. *Capsella bursa-pastoris* (L.) Medic., and *Medicago lupulina* L. were susceptible to the yellow dwarf virus. Among the suscepts reported by Black (1,3) the following may be considered as weeds: *Trifolium agarium* L., *T. repens* L., *Cichorium Intybus* L.

Observations indicating that the potato yellow dwarf virus may spread in the absence of cultivated clovers have made it desirable, first, to determine the susceptibility of the common weeds occurring in areas where the yellow dwarf disease is most serious; and second, to determine which of the suscepts are commonly infected under field conditions.

Weed Suscepts

A collection of weed seeds made during the summer of 1940 consisted mainly of species encountered in areas where yellow dwarf is a common disease. Seedlings of the different species of weeds were grown in the greenhouse until they were from two to four weeks old, when they were large enough to support from five to ten clover leafhoppers (*Acertagallia sanguinolenta* Prov.). Five plants of each species were individually caged and from five to ten infective clover leafhoppers were introduced into each cage. The insects were allowed to feed from three to four weeks. At the end of this period the insects and cages were removed and the plants tested for the presence of the yellow dwarf virus. *Nicotiana rustica* L. was used as a test plant. The leaves of the tobacco plants were mechanically inoculated with juice extracted from the different weeds. All the equipment was sterilized before it was used and hands were thoroughly washed after each inoculation to avoid transfer of the virus from preceding plants. After a period varying from three to four weeks the inoculated tobacco plants were examined for the presence of the typical local and systemic symptoms of the yellow dwarf virus which have been described by Black (2). If the tobacco plants which had been inoculated with the juice from a specific weed, exhibited systemic yellow dwarf symptoms in two separate trials, that weed was regarded as infected (table 1). Negative results have been tentatively regarded as inconclusive and have not been reported.

Symptoms expressed by *Rudbeckia hirta* L., *Anthemis Cotula* L., *Galinsoga cilata* (Raf.) Blake, *Lepidium virginicum* L., *L. Campestre*

TABLE 1.—*New weed hosts from which the potato yellow dwarf virus was transmitted to Nicotiana rustica*

New Suspect	Duration	No. Plants Inoculated	No. Plants Infected
Chrysanthemum leucanthemum	Perennial	5	4
Tragopogon pratensis	Biennial	5	4
Rudbeckia hirta	Biennial	5	2
Anthemis Cotula	Annual	5	2
Galinsoga ciliata	Annual	5	2
Lepidium campestre	Winter Annual	5	3
L. virginicum	Biennial	5	2
Brassica nigra	Annual	5	1
Sisymbrium altissimum	Winter Annual	5	2
Erysimum cheiranthoides	Biennial	5	2
Verbascum Thapsus	Biennial	5	2
V. Blattaria	Biennial	5	3
Rumex crispus	Perennial	5	1
R. obtusifolius	Perennial	5	2
Leonurus Cardiaca	Perennial	5	2

(L.) R. Br., *Brassica nigra* (L.) Koch, *Sisymbrium altissimum* (L.) Scop., *Erysimum chieranthoides* L., *Verbascum Blatteria* L. *Rumex crispus* L., and *Leonurus Cardiaca* L. were mild, while successfully inoculated plants of *Chrysanthemum leucanthemum* L. var. *pinnatifidum* Lecoq. & Lamotte, *Tragopogon pratensis* L., *Verbascum Thapsus* L., and *Rumex obtusifolius* L. displayed pronounced symptoms. The symptoms expressed by all plants were essentially similar, although they differed widely in their severity. *T. pratensis* was killed, whereas most of the remaining species eventually recovered sufficiently so that all symptoms disappeared. *V. Thapsus* was an exception because eight months after inoculation pronounced symptoms were still evident. The symptoms manifested by chrysanthemums* will serve to illustrate the type of reaction most commonly observed, although the response of most weeds was much less severe. Vein clearing of the youngest leaves was the first symptom observed. Such leaves remained small for a time, and became distorted, stiff and apparently thicker than healthy leaves. The petioles failed to elongate normally and thus a rosette consisting of numerous distorted, small, stiff leaves formed about the crown of the plant. Later these leaves expanded, their petioles elongated somewhat, veins became light green in color, and the leaves assumed an erect position. Leaves subsequently formed apparently expanded to a nearly normal

*Chrysanthemum as used hereafter applies only to *Chrysanthemum leucanthemum* var. *pinnatifidum*.

size and could be distinguished from healthy leaves only by their dark green color and erect habit. In one chrysanthemum the virus was found to be present five months after marked symptoms disappeared, indicating that the disappearance of the symptoms was not associated with a loss of the virus.

Field Studies

Two farms in Steuben County, New York, on which potato yellow dwarf has been prevalent for at least ten years, were selected for field experiments. Both farms were located on hillsides and a considerable portion of each farm was either planted to clover or uncultivated and supported a large weed population. Throughout the summer of 1941 weed suscepts were collected from these farms, transplanted to pots and tested in the greenhouse at Ithaca for the presence of the yellow dwarf virus. *Nicotiana rustica* was used as a test plant as has been described above.

In May, 50 chrysanthemums were selected at random from fields on each of the two farms. From farm No. 1, 16 of these plants gave a positive yellow dwarf reaction on *Nicotiana rustica,* whereas 7 plants from farm No. 2 reacted positively (table 2). Scions from the success-

Table 2.—*Transmission of the potato yellow dwarf virus from naturally infected Chrysanthemum leucanthemum var, pinnatfidum to Nicotiana rustica*

Date of Collection	Farm No.	No. Plants Collected	No. Plants Infected	Percentage of Plants Infected
May	1	50	16	32.0
May	2	50	7	14.0
June	1	48	40	83.3
June	2	48	18	37.5

fully inoculated *N. rustica* plants were grafted on healthy Green Mountain potato plants and typical yellow dwarf symptoms were observed on the potatoes six weeks later. Non-infective clover leafhoppers which were fed on suspected chrysanthemums, successfully transmitted the yellow dwarf virus to crimson clover (*Trifolium incarnatum* L.) where typical yellow dwarf symptoms were produced. In June, a second collection of chrysanthemums was made from each farm. A total of 48

plants suspected of having yellow dwarf were collected from farm No. 1, whereas 48 plants from farm No. 2 were collected at random. In the first case 40 plants were found to have yellow dwarf, and in the second case 18 plants were infected.

Counts were made in three fields to determine the percentages of chrysanthemums showing symptoms. Fifty plots, one square foot in area, were selected at random and counts were made of the total number of chryanthemums and the number showing yellow dwarf symptoms. In one field on farm No. 1, 14.1 per cent of the plants showed yellow dwarf symptoms (table 3), whereas in another field on the same

TABLE 3.—*Estimates of the number of plants of Chrysanthemum leucanthemum var. pinnatifidum infected with the potato yellow dwarf virus based on symptoms*

Field No.	Total No. Showing Symptoms	Total No. Plants Counted	Percentage Showing Symptoms	Average No. Infected per Sq. Ft.
1—farm 1	133	944	14.1	2.6
2—farm 1	108	352	30.6	2.1
3—farm 2	157	566	27.7	3.1

farm 30.6 per cent of the plants appeared to be infected. In the field on farm No. 2, 27.7 per cent of the chrysanthemums were apparently infected.

It was pointed out earlier that the symptoms of the yellow dwarf virus often disappeared under greenhouse conditions, and therefore it seemed desirable to determine to what extent this apparent recovery might influence estimates of infected chrysanthemums in the field. From an area of four square feet on farm No. 2, all of the chrysanthemums (a total of 135) were removed. A total of 122 plants survived the transplanting operations and were tested for the presence of the yellow dwarf virus. Of these, 82 plants, or 67.2 per cent, gave a positive yellow dwarf reaction on *Nicotiana rustica*. Thus it appeared obvious that estimates based on symptoms were extremely conservative.

Extensive tests have been made on Medium Red clover (*Trifolium pratense* L.) in an attempt to determine to what extent this plant serves as a yellow dwarf suscept. Collections were made at random in clover fields and in weed fields where infected chrysanthemums were abundant. A total of 627 plants was tested on *Nicotiana rustica* and only one plant gave a positive yellow dwarf reaction. It may be significant to note that the infected clover plant was taken from a weed field. In another

experiment non-infective clover leafhoppers were caged on 100 clover plants collected from a weed field on farm No. 1. The insects were allowed to feed for a three-week period and were then transferred to crimson clover seedlings. After eight weeks none of the crimson clover plants had become infected.

The above experiments seemed to indicate that the chrysanthemum is a more important suscept than clover. In order to test this further 48 collections of 5 insects were made at 48 stations evenly distributed over a clover field on farm No. 2, and similarly 48 collections were made in a nearby weed field where infected chrysanthemums were abundant. The insects were caged on crimson clover seedlings at each station immediately after collection and allowed to feed on these plants for eight weeks. At the end of the period 29.1 per cent of the crimson clover plants supporting insects from the weed field were infected, while none of the plants supporting insects from the clover field was infected. This experiment was later repeated with almost identical results.

A series of tests was also conducted on *Rudbeckia hirta*. A total of 211 plants was tested from farms No. 1 and No. 2. One plant gave a positive reaction for yellow dwarf on *Nicotiana rustica*. Less extensive tests were made with *Barbarea vulgaris*. From a total of 84 plants tested, one was found to be infected.

SUMMARY

Fifteen new weed suscepts of the potato yellow dwarf virus are reported.

Limited evidence is presented which indicates that *Chrysanthemum leucanthemum* var. *pinnatifidum* may be a more important source of the potato yellow dwarf virus under field conditions than Medium Red clover.

The presence of the yellow dwarf virus was demonstrated in naturally infected plants of the following species: *Chrysanthemum leucanthemum* var. *pinnatifidum*, *Trifolium pratense*, *Rudbeckia hirta*, and *Barbarea vulgaris*.

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COMPARISON OF KATAHDIN POTATO POLLEN PRODUCED IN THE FIELD AND IN THE GREENHOUSE

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Studies were conducted in the field and in the greenhouse at Greeley, Colorado, at an elevation of 4,800 feet and in the field at Estes Park at an elevation of 7,500 feet in 1939 to determine the effect of growing conditions on the percentage of stainable pollen from well-advanced buds and from blossoms of the Katahdin potato. In most years the crosses made at Estes Park were quite successful, although in some years most of the crosses did not produce seed.

Pollinations in the field at Greeley, however, have generally met with little success because of unfavorable climatic conditions. Although no accurate weather reports are available for Greeley, they are available for Denver, which is only 50 miles away and has an altitude of approximately 5,200 feet. According to the Weather Bureau report the average maximum temperature at Denver for July 1939 was 90.2° F., and the average minimum temperature was 64°; for August the averages were 85° and 64°. The average relative humidity for July at 5:30 a. m. was 53 per cent; at noon, 23 per cent; and at 5:30 p. m., 20 per cent; for August the readings were 62, 29, and 28 per cent, respectively. At Estes Park the temperature during the growing season is about 10° to 15° lower than that at Greeley, and the relative humidity is somewhat higher.

Previous studies with 9-, 11-, 13-, and 17-hour photoperiods in the greenhouse indicated that the different photoperiods have no effect on the percentage of stainable pollen (*1*). In the present test the greenhouse plants were given a 16-hour photoperiod. In the field the photoperiod varied from approximately 15 hours at time of emergence to nearly 14 hours at the time the blossoms were gathered. A night temperature of 55° F. and a day temperature of 70° to 75° were maintained in the greenhouse, although the day temperature was higher for short periods in the afternoon. A humidity of 75 to 85 per cent was maintained by sprinkling the walks and soil under the benches. The humidity, however, would drop for short periods when the ventilators were opened to lower the temperature.

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Our studies were made with the Katahdin variety, using advanced buds and blossoms. Care was taken to select buds just ready to open and blossoms 2 or 3 days after opening, but before the anthers had begun to shrivel. All the buds and blossoms selected showed five well developed anthers. Pollen grains from the greenhouse plants were examined as soon as possible after collecting. From field-grown plants buds and blossoms were gathered and placed in a fixing agent for 30 hours, after which they were transferred to 70-per cent alcohol until the pollen could be examined. The fixing agent consisted of 90 cc. of 50-per cent alcohol, 5 cc. of commercial formaldehyde solution, and 5 cc. of glacial acetic acid.

There was considerable variation in the amount of pollen that could be extracted from individual anthers in the same bud or flower, from different buds, and from different flowers. Although no satisfactory method has been devised for measuring the quantity of pollen, observations seem to indicate that blossoms developed in the greenhouse produce a larger amount of pollen than is normally produced in the field at Greeley or Estes Park as shown in figure 1, and that a larger amount

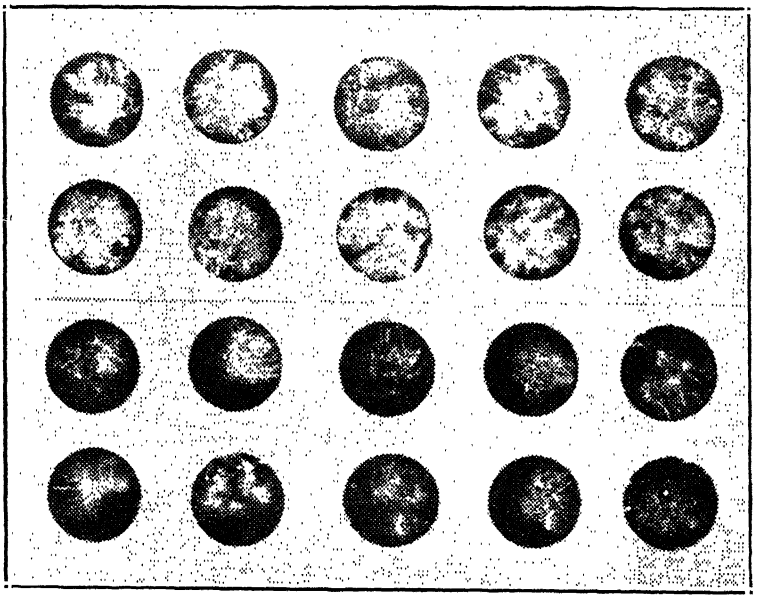

FIG. 1.—*Comparison of amount of pollen from Katahdin flowers produced in the field and in the greenhouse at Greeley, Colo. Each disk contains the pollen from a single blossom: Two upper rows, from flowers in the greenhouse two lower rows, from flowers in the field.*

of pollen can be removed from mature anthers after they become dry than from the immature anthers of well-advanced buds.

The percentage of stainable pollen of a bud or flower was determined for each anther separately. Pollen grains of the buds were inclined to clump, making counting more difficult. They were more mature and drier in older blossoms and separated better when placed on the slide.

A small amount of pollen from each anther was placed on a slide, a drop or two of acetocarmine was added, the cover glass was applied, and the preparation was heated slightly to hasten the staining. In a few minutes many of the pollen grains became dark, whereas the others colored slightly or remained unstained. It is assumed that the grains taking a dark stain were functional, but their viability was not determined by germination tests.

The counting of a field of pollen was made comparatively easy by the use of an ocular micrometer. A total of 750 to 1,200 pollen grains were examined from each bud or blossom. The data in table 1 show

TABLE 1.—*Percentage of stainable pollen grains of well-advanced buds and blossoms produced by Katahdin potato plants grown in the field and in the greenhouse. Means of 50 plants*

Treatments	Stainable Pollen	
	Per cent	S.E.
1. Advanced buds, greenhouse, Greeley	70	± 0.59
2. Blossoms, do do	75	± 0.46
3. Advanced buds, field, Greeley	64	± 1.41
4. Blossoms, do do	67	± 1.03
5. Advanced buds, do, Estes Park	72	± 0.69
6. Blossoms, do do	72	± 0.62

that there is a significant difference in percentage of stainable pollen between advanced buds and blossoms produced by plants grown in the greenhouse at Greeley; but there is no significant difference between advanced buds and flowers produced in the field at Greeley. There is a highly significant difference in percentage of stainable pollen between advanced buds produced in the greenhouse and those produced in the field at Greeley; but the difference in percentage of stainable pollen between advanced buds in the greenhouse at Greeley and those in the field at Estes Park is significant to only the 5-per cent level. There is also a highly significant difference in percentage of stainable pollen

between advanced buds produced in the field at Greeley and those produced at Estes Park.

In comparing the percentages of stainable pollen from blossoms it will be noted that there are highly significant differences between blossoms from the greenhouse and from the field at Greeley, also between blossoms produced in the greenhouse and those produced in the field at Estes Park, and between blossoms produced in the field at Greeley and those at Estes Park.

A greater variation in the percentage of stainable pollen was often found among anthers of the same flower than among different flowers. The lowest percentage of stainable pollen examined was from an anther produced by a plant grown in the field at Greeley. This anther produced only 7.9 per cent stainable pollen. The lowest percentage of stainable pollen from an individual flower was 37 per cent and the highest 83 per cent.

Krantz *et al.* (2), working in Minnesota, found that "clones may vary in percentage of stainable pollen between periods within a season, the amount of variation depending upon environmental conditions." Although there are significant differences in the percentage of stainable pollen between advanced buds grown in the greenhouse and those in the field at Greeley and at Estes Park, and significant differences in the fertility of pollen from blossoms produced in the greenhouse and those in the field at Greeley and in the field at Estes Park, these differences are not sufficient to influence fertilization after pollination. Fertilization occurs even when pollen with a very low percentage of stainable pollen is applied. Bliss Triumph and Irish Cobbler have been selfed successfully in the greenhouse at Greeley, although a very low percentage of the pollen was stainable.

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TREATMENT REMOVES RHIZOCTONIA FROM POTATO TUBERS

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Since washing potatoes is often necessary to prepare them for market, especially when they must be dug from wet soil, new disease problems have arisen. Bacterial ring rot and certain storage diseases may be disseminated in the wash water. A suitable disinfectant added to the rinse water is thought advisable.

While working on this problem a number of disinfectants were tried, including calcium hypochlorite. It was noted that Rhizoctonia sclerotia on tubers which were allowed to remain in a solution of this chemical for several hours disintegrated or loosened to such a degree that they were easily removed by light brushing in water. Also it appeared that the outer rough surface of the tubers was oxidized slightly and bleached resulting in a fresh often pinkish color resembling new potatoes. The appearance of Cobbler and Early Ohio potatoes was greatly improved even though the tubers were not infected with Rhizoctonia. The treatment did not appear to be injurious in any way to the development of healthy sprouts from the eyes of potatoes.

Commercial chlorinated lime containing 24 per cent available chlorine has been used. Soaking the tubers 15 hours in a cold 5 per cent solution of chlorinated lime followed by light brushing in water has given good results. The time of exposure to the solution may be varied considerably either by varying the strength or by changing the temperature of the solution. In some tests a 10 per cent cold solution produced results in 6 hours and in other tests a 5 per cent solution held at 100° F. required only one hour. Different wetting agents added to the solution were tried but their value in long time soaking tests seems questionable.

It is believed that the chlorinated lime treatment may prove very useful from a number of standpoints, namely: (1) as a disinfectant for table stock potatoes, (2) as a detergent to remove Rhizoctonia and to improve appearance of marketable potatoes, (3) as a preventive against decay of tubers in transit and in storage, and (4) a promising

*Published with the approval of the Director of the North Dakota Agricultural Experiment Station.

treatment to prevent dissemination of bacterial ring rot and other diseases from seed stock.

Many questions concerning this new treatment are yet unanswered. It is reported here as a treatment worthy of further trial by other workers. It is recognized that many engineering problems may be involved in the practical application of the treatment. Extended tests under North Dakota conditions are under way.

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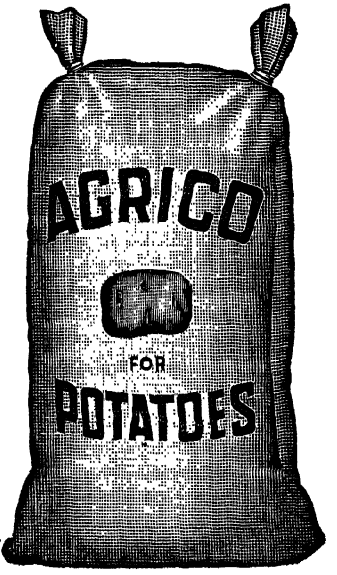

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PREVENTION OF POTATO SEED PIECE DECAY[1]

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Perfect stands of potatoes in the field and vigorous growth of the plants following their emergence depend largely upon preservation of the seed pieces from decay. Complete early decay of seed pieces is most harmful to the stand but early partial decay is also injurious because the resulting plants lack vigor. The plant food materials stored in the potato tuber are necessary for the development of fast growing, vigorous sprouts and also to the initiation of an abundant root system. The potato plant at first depends entirely on the seed piece for plant food and water, but later depends more and more on its roots for these materials. Greatest vigor of growth results when the seed piece remains sound so all its stored food materials can be utilized by the plant. It is consequently desirable that the seed piece remain sound not only until after the sprouts have emerged but until all stored food has been utilized by the plant.

The object of this paper is to present results of investigations on methods that have been found beneficial under eastern Kansas conditions for preventing planted potato seed pieces from decaying.

METHODS

Various pre-planting treatments of potato tubers or cut seed pieces were made annually during the six-year period of this investigation. Plantings of the variety Irish Cobbler were made during the latter part

[1]Presented as Contribution No. 428, Department of Botany.

of March in various fields in the commercial potato-growing section of eastern Kansas. The seed pieces planted in the various field trial plots were spaced at six-inch intervals in quadruplicated rows 50 feet long. Plant emergence began during the latter part of April. Alternate plants, including the seed pieces, were removed from the soil during May for data concerning Rhizoctonia infections on stems and stolons, and also regarding the state of preservation of the seed pieces. At the time these records were taken the potato plants were beginning to bloom and to set tubers. The remaining plants, spaced 12 inches apart, were allowed to grow to maturity in order to obtain yield data.

Results

The results obtained during this investigation indicate that under eastern Kansas conditions potato seed piece decay can largely be prevented through appropriate fungicidal seed treatments.

Seed piece decay was unusually serious in many commercial potato fields of eastern Kansas during the season of 1935. This was particularly true in fields planted with untreated seed. A large percentage of the seed pieces in such fields decayed before the sprouts were produced and many of the plants that emerged lacked vigor because of early partial seed piece decay. Satisfactory stands and generally vigorous plants developed in those fields planted with seed that had been treated with acidulated corrosive sublimate.

Serious amounts of seed piece decay did not occur in Kansas during the seasons 1936 to 1940 inclusive. The reason for this reduction from that of 1935 has not been determined but excessive soil moisture evidently was not the cause for the unusual prevalence of decay in 1935. According to the U. S. Weather Bureau records from Topeka, the rainfall during March and April was less in 1935 than it was during any of the remaining five seasons of this investigation.

Results from the experimental trial plots of this investigation indicate that potato seed piece decay was effectively prevented by certain seed treatments. A high degree of seed piece preservation followed the treatments with acidulated corrosive sublimate and with yellow oxide of mercury. As shown in table 1,—only 27.7 per cent of the untreated seed pieces were sound in May, 1935 when these data were obtained. Of the seed pieces from tubers that were treated with acidulated corrosive sublimate and with yellow oxide of mercury, 91.7 and 94 per cent respectively remained sound. Hot formaldehyde treatments proved somewhat less effective for preventing seed piece decay than did the mercurials.

During 1936 to 1940, inclusive, the variation in percentage of sound seed pieces ranged from 75.3 to 83.1 with an average of 79.5. Ten-minute treatments of uncut tubers in a solution containing one part corrosive sublimate to 500 parts water with one per cent hydrochloric acid (approximately six ounces to 25 gallons with one quart acid) were followed by an average of 94.4 per cent sound seed pieces. Dip treatments of uncut tubers in a solution of one pound yellow oxide of mercury to 15 gallons of water were followed by an average of 96.9 per cent sound seed pieces whereas tubers that had been treated with hot formaldehyde had an average of 93.7 per cent sound seed pieces.

Certain solutions containing concentrations of corrosive sublimate higher than one part to 500 parts water were among the fungicidal solutions tested for controlling Rhizoctonia at the time the seed piece preservation investigations were in progress. Records were obtained on the effect of these momentary dip treatments on preservation of the seed pieces.

Momentary dip treatments of potato tubers in solutions containing three, four and five parts of corrosive sublimate to 500 parts water acidulated by one per cent hydrochloric acid proved effective for preventing seed piece decay. An average of 99 per cent of the seed pieces remained sound, following a momentary dip of the uncut tubers in the three to 500 and the four to 500 solutions and 97.3 per cent remained sound following the dip treatment in the five to 500 solution as shown in table 1.

Momentary dip treatments in the acidulated solution containing one part corrosive sublimate to 500 parts water were less effective for preventing seed piece decay than were the momentary dip treatments in the higher concentrations of corrosive sublimate. From these results and from results obtained in Rhizoctonia control tests it appears that tubers dipped momentarily in the one to 500 concentration solution carry an insufficient "load" of corrosive sublimate either for sterilization of surface-borne Rhizoctonia sclerotia or for effective preservation of the seed pieces. An adequate "load" of corrosive sublimate for sterilization of Rhizoctonia sclerotia and for prevention of seed piece decay is, however, carried on the tubers following the momentary dip treatments in the higher concentration solutions.

Comparisons were also made on subsequent development of seed piece decay, following treatments of the whole tubers and of cut seed pieces in the ten-minute soak in one to 500 concentration and in the momentary dip in three to 500 concentration corrosive sublimate. The results indicate that no significant differences in seed piece preservation resulted either

TABLE 1.—*Potato seed piece preservation through fungicidal seed treatments*

Seed Treatment	Number Test Plots	Total Number Seed Pieces	Seed Pieces Sound	
			Number	Per Cent
Results in 1935				
Untreated	7	1958	542	27.7
Acid. $HgCl_2$ 1-500 + 1% HCl-10 min.	5	1543	1406	91.7
Yellow oxide of mercury 1 lbs-15 gal. min.-dip	4	783	736	94.0
Hot formaldehyde 1-120 at 125°F.-5′	2	377	288	76.4
Results 1936-1940 (average)				
Untreated	32	7056	5607	79.5
Acid. $HgCl_2$-1-500 + 1% HCl-10′-Whole tubers	32	6378	6019	94.4
Acid. $HgCl_2$-1-500 + 1% HCl-10′-cut seed	11	1989	1856	93.3
Acid. $HgCl_2$-1-500 + 1% HCl-dip-whole tubers	6	1077	961	89.2
Acid. $HgCl_2$-3-500 + 1% HCl-dip-whole tubers	17	3194	3072	99.0
Acid. $HgCl_2$-3-500 + 1% HCl-dip-cut seed	6	1086	1038	95.6
Acid. $HgCl_2$-4-500 + 1% HCl-dip-whole tubers	6	1336	1322	99.0
Acid. $HgCl_2$-5-500 + 1% HCl-dip-whole tubers	14	2810	2733	97.3
HgO-1 lb. to 15 gal.-dip-whole tubers	16	3095	3000	96.9
Hot formaldehyde	4	742	695	93.7

following the treatments of the whole tubers or of the cut seed. These data indicate that applications of corrosive sublimate to the cut surfaces do not result in increased seed piece preservation. The most rapid decay of potato seed pieces in Kansas is the common watery soft rot which usually begins on the uncut surface. It seems probable that prevention of this soft rot is more dependent on a bactericidal protection of the uncut outer surfaces than of the cut surfaces.

Other fungicidal materials tested as protectants against potato seed piece decay included red oxide of copper, calomel and various organic mercury compounds. These materials did not provide as effective seed piece preservation as did acidulated corrosive sublimate. Other investigations included suberization of cut seed potatoes and the coating of the seed pieces with dry hydrated lime, gypsum, sulfur, and equal parts of hydrated lime and sulfur. Preplanting suberization of the cut seed was not so effective for preventing seed piece decay as were treatments with acidulated corrosive sublimate or with yellow oxide of mercury. The inconvenience to growers, of holding the cut seed under the required temperature and humidity conditions preclude the general use of this method, especially when large acreages are planted. The coating of potato seed pieces with lime, gypsum, sulfur, and equal parts of lime and sulfur were less effective for preventing seed piece decay than were treatments with acidulated corrosive sublimate or yellow oxide of mercury.

Acidulated corrosive sublimate, in addition to being efficient for preventing the decay of potato seed pieces is also highly effective for the sterilization of tuber-borne Rhizoctonia sclerotia. Yield increases following seed treatments with this fungicide doubtlessly are no doubt partly caused by seed piece preservation rather than to prevention of the Rhizoctonia disease alone. None of the other fungicides tested, including yellow oxide of mercury and hot formaldehyde, proved so effective for preventing the Rhizoctonia disease. Investigations during the past two seasons indicate that treatment of the cut seed with acidulated corrosive sublimate is also highly effective for preventing the spread of ring rot bacteria from infected to non-infected seed pieces during planting operations.

A NEW FORM OF LOW-TEMPERATURE INJURY IN POTATOES

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Chippewa, Katahdin, and Irish Cobbler potatoes with an internal reddish-brown discoloration were received from several commercial storage houses in Maine during March, 1938. This discoloration resembled the blotch type of freezing injury inasmuch as it occurred in irregular patches in the vascular ring, cortex, and, occasionally, the pith. The fact that these varieties were more affected by this discoloration also suggested low-temperature injury because laboratory and storage tests (unpublished; by Donald Folsom) had shown them to be more susceptible to freezing than other varieties grown in Maine. Further, in commercial storages the potatoes usually were more severely affected in a part of the storage bin where the temperature would be the lowest. However, the discolored part of the tuber was reddish-brown instead of being of varying shades of gray to black as is typical of freezing injury. An examination of numerous specimens showed that the new kind of discoloration varied from "benzo brown" and "sorghum brown" to "fawn color" as designated by Ridgway (3). The injury is often mistaken for a form of late-blight injury by seed buyers and farmers.

The Cause

Experiments were conducted in 1938, 1939, and 1940 with a controlled freezing apparatus in an attempt to reproduce the reddish-brown injury. The various types of freezing injury, net, ring, blotch, and leaker, as described by Jones, Miller, and Bailey (2) and by Wright and Diehl (4), were produced in all varieties in one test or another when tubers were frozen at temperatures ranging from 21° to 27° F., and for periods ranging from 1 to 72 hours. In all these tests, however, the discolored part of the affected tubers was gray or black and the reddish-brown color was not reproduced. Specimens continued to be received from commercial growers and those in charge of potato storage houses, among whom the malady became known as "mahogany rot". These specimens were usually received in March and April and

apparently the potatoes in storage were not affected previous to March. This suggested that the physiological state of the tuber might influence the kind of color produced by low temperature and therefore more elaborate experiments were conducted in 1939 and 1940, varying the date and time of exposure, the temperature, the rate of fall of the temperature, the kind of storage during thawing, and the length of the thawing period. In none of these tests, however, was the so-called mahogany rot reproduced. The longest time of freezing was 96 hours.

Longer exposures under controlled conditions resembling those of commercial storage houses became possible in the fall of 1940 through a new set of experimental potato storage bins made available as a part of the Station equipment at Aroostook Farm in northeastern Maine. Consequently an experiment was planned in which the prolonged effect of low temperature at different humidities was studied.

Tubers were stored in five places: an apple cold storage room at Highmoor Farm in southwestern Maine, with temperature kept by manual control between 33 and 35° F.; a basement room of the Station building at Orono in central Maine, with temperature rarely below 32° F. and kept below 40° F. during most days by means of an open window to the outside but running up to approximately 60° F. at night; experimental potato storage rooms at Aroostook Farm, respectively with temperature at 32° F. and relative humidity at about 90 per cent, with temperature at 32° F. and relative humidity at about 75 per cent; and with temperature at 38° F. and relative humidity at about 75 per cent.

In each place one barrel was stored from each of these stocks: healthy Green Mountain, healthy Chippewa, leaf roll Chippewa, and partly leaf roll Katahdin grown in Station plots at Highmoor Farm; healthy Green Mountain, healthy Chippewa, and healthy Katahdin grown at Aroostook Farm.

Thirty tubers from each barrel in the apple cold storage room were examined in early November and this was repeated on the 7th of March. No discoloration was found. Some of the reddish-brown discoloration was found on the 20th of April when many more tubers were examined. This discoloration was restricted to Chippewa and Katahdin tubers and was rare outside of the leaf roll stock.

The potatoes stored at Orono were used for controlled freezing work and numerous artificially frozen and unfrozen tubers were examined from each barrel during each week until the end of the experiments in May. At no time was any type of discoloration found except that usually produced by controlled freezing.

Samples were first taken from the experimental storage bins at

Aroostook Farm on the 15th of March. Ten tubers were examined from each barrel. A mahogany discoloration, typical of that found in commercial storages, was found in the Chippewa and Katahdin lots that were stored at 32° F. at both percentages of relative humidity. No discoloration was found in the Green Mountain stored under these conditions. (Fig. 1) In the Chippewa variety the discoloration was

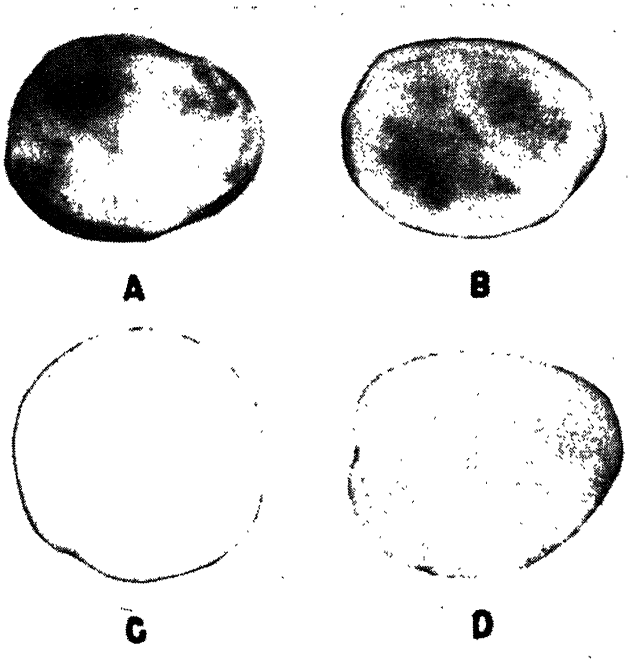

FIG. 1. Tubers cut after several months in experimental storage rooms. A and B, Chippewa at 32° F. and 75 per cent relative humidity. C, Green Mountain kept with A and B. D, Chippewa at 38° F. and 75 per cent relative humidity. The discoloration was reddish-brown.

equally severe at the two percentages of relative humidity, but in the Katahdin variety there was more discoloration at 75 per cent than at 90. There was a constant difference in the location of hte injury when the leaf roll Chippewa tubers were compared with the healthy, the injury being more localized in the cortex in the leaf roll tubers. In the partly leaf roll Katahdin tubers this localization of the injury was not so pronounced. There was a tendency for the healthy tubers grown in southwestern Maine to show more injury than those of the same susceptible variety grown in northeastern

Maine. At no time was discoloration found in any of the Chippewa or Katahdin lots kept at 38° F. and 75 per cent relative humidity. (Fig. 1, C and D) Sampling was continued at weekly intervals from the 15th of March until the 21st of April. On the 3d of April, half of each lot stored at 38° F. and 75 per cent relative humidity was shifted to the room with 32° F. and 75 per cent relative humidity. There no discoloration was found up until the 21st of April, so that it appeared that an exposure of nearly 3 weeks was not enough to produce the injury at that time of year.

The writers prefer to call this type of low-temperature injury "internal mahogany browning" rather than "mahogany rot", as the latter name implies that the discoloration is caused by an organism. All attempts to isolate an organism have given negative results. Although it has been shown here that internal mahogany browning can be caused by long exposure to temperatures that approximate 32° F., the various combinations of time and temperature that may produce the discoloration are not yet known. Possibly the production of this color is influenced by the physiological state of the tuber.

This kind of low-temperature injury differs from other kinds inasmuch as tubers with typical mahogany browning showed a greenish fluorescence under ultra-violet radiation, while tubers with the net, ring, blotch, and leaker types of freezing injury occasionally exhibited a fluorescence which was more bluish in color. The leaf roll Chippewa tubers with the mahogany browning in the cortex exhibited a fluorescence more greenish than that of the other tubers, and indistinguishable from the fluorescence of tubers infected by bacterial ring rot, despite the absence of ring rot. Flint and Edgerton (1) have noted that fluorescence is of little value in conforming infection by ring rot, as they found that tubers infected with stem-end rot as well as ring rot fluoresce. In addition, it appears, here that the internal mahogany browning caused by the low temperature may also interfere with the usefulness of fluorescence for the determination of ring rot.

Effects in the Field

An experiment was conducted in 1940 with the Chippewa and Katahdin varieties to determine whether this discoloration affects the value of the potato for seed purposes. A seed stock of each of these varieties was divided into three lots, with respect to the degree of internal discoloration. One lot contained seed tubers which had no apparent discoloration; the second lot contained tubers with a slight

to a medium amount of discoloration; and the third contained seed which was very severely discolored and which contained some internal breakdown and decay. The seed of both varieties was relatively free from the virus diseases.

The data pertaining to this experiment are summarized in table 1, and indicate that the stand was not significantly reduced by a slight

TABLE 1.—*Comparison of stand and yield when using Katahdin and Chippewa seed stock having different degrees of internal discoloration*

Variety	Extent of Discoloration in Seed Stock	Percentage of Stand	Yield per Acre in Barrels	Reduction in Yield Rate in Barrels
Chippewa	None apparent	98	133 ± 3.70	—
	Slight to medium	95	111 ± 2.87	22
	Severe, tubers darkened throughout	83	79 ± 2.69	54
Katahdin	None apparent	97	89 ± 2.20	—
	Slight to medium	94	85 ± 3.25	4
	Severe, tubers darkened throughout	89	65 ± 2.91	24

or medium amount of the internal discoloration. This confirms observations made by the writers during previous years when tubers having internal mahogany browning produced normal appearing plants and no apparent reduction in yield. The stand, however, was affected provided the discoloration was severe. Many of the severely affected seed pieces decayed when planted, producing missing hills or small weak plants.

The data indicate that the yield may be reduced by planting a seed stock generally affected with internal discoloration of this kind. A slight to medium amount of discoloration in all of the seed pieces in the Chippewa variety reduced the yield 22 barrels per acre in comparison with a part of the same seed stock without the discoloration. This reduction in yield is significant for this experiment. This slight to medium amount of discoloration in all of the seed tubers reduced the yield only 4 barrels per acre in the Katahdin variety. The yield

was significantly reduced in both varieties by planting seed from severely affected tubers. The reduction in yield was 54 barrels per acre for the Chippewa variety and 24 barrels for the Katahdin variety.

The writers believe that the presence of a small percentage of slightly affected tubers in a seed stock will not materially affect its value for planting.

Summary

A so-called "mahogany rot", for which the name "internal mahogany browning" is proposed, is caused by long exposure to medium low temperature. Chippewas and Katahdins stored at 32° F. through the winter exhibited the reddish-brown discoloration by March. No injury was shown by the same varieties stored at 38° F., or by Green Mountains stored at 32° F. Leaf roll aggravated the injury in Chippewas.

Exposure to lower temperatures for short periods produced the usual freezing injury in all varieties. This injury occasionally exhibited a fluorescence, and this fluorescence was more bluish than the greenish fluorescence of internal mahogany browning. Leaf roll accentuated the greenish fluorescence, so that it was indistinguishable from the fluorescence of tubers infected by bacterial ring rot.

Internal mahogany browning may reduce the stand and yield rate of a field planted with seed showing the injury.

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RELATIVE RESPONSE OF SEVERAL VARIETIES OF POTATOES TO PROGRESSIVELY CHANGING TEMPERATURES AND PHOTOPERIODS CONTROLLED TO SIMULATE "NORTHERN" AND "SOUTHERN" CONDITIONS

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In view of the economic inter-relationship of northern and southern potato-growing districts, resulting from the practice of growing seed in the north for southern planting, a thorough knowledge of the adaptability of varieties to both regions is desirable. Since numerous field trials had failed to provide clear cut information regarding the difference in response of two strains of Triumph potatoes in various localities as well as they were determined with controlled environmental tests (3, 4), it was deemed advisable to determine the response of varieties representing distinct types under conditions simulating northern and southern conditions.

EXPERIMENTAL METHODS

In tests conducted in the greenhouses at Lincoln from October 1936 to March 1937, the following technique was used: Warba and a very early strain of Triumph (T12) were selected as typical of varieties producing earliest tubers; Irish Cobbler and Chippewa were chosen as intermediate season varieties, and a late strain of Triumph (T23), was used in addition to Katahdin and Russet Rural as typical of late varieties. Seed pieces were planted in sand on the 1st of October and in late October pieces with sprouts, of similar size, were shifted to 10-inch clay pots filled with sand. The plants emerged above the surface about the 1st of November, the date used for calculating the age of the plants. A complete nutrient solution was supplied at frequent intervals as in earlier experiments (2, 4).

Photoperiods of desired duration were secured by the use of electric lights (about 70 foot candles at tops of plants). These were turned on at 7 A. M. and used until daylight was brighter than the artificial light and they were left on until turned off by automatic control at the

[1]Published with the approval of the Director, Journal Series No. 277 of the Nebraska Agricultural Experiment Station, December 19, 1940.

desired time. Changes in light duration and temperature were made at weekly intervals as depicted in figure 1. At designated times three plants were harvested from each variety growing under each condition.

FIG. 1.

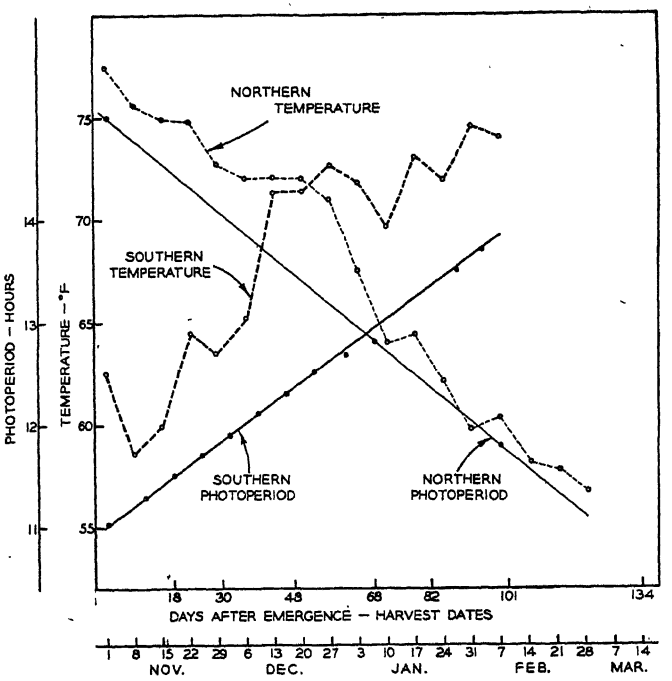

FIG. 1. Mean temperature and mean length of photoperiod for each week ending on date specified for plants grown with northern and southern conditions.

EXPERIMENTAL RESULTS AND DISCUSSION

Vegetative growth of "northern condition" plants differed from "southern condition" plants of the same varieties in being more rapid, continuing to a later date and attaining a greater maximum size as shown in table 1. Northern condition plants developed three or more stem axes, whereas southern condition plants seldom produced more than the main axis. "Northern" plants attained maximum vegetative weight slightly later than the "southern plants," the decline caused by senility was slower and later. Under southern conditions the vegetative weight of late varieties dropped off less and later in the season than with early

TABLE I.—*Fresh weight of vegetative parts (grams per plant) produced by each variety under "northern" and "southern" conditions*

Days after Emergence	Warba	Triumph 12	Irish Cobbler	Chippewa	Triumph 23	Katahdin	Russet Rural
			NORTHERN CONDITIONS				
18	87	85	47	72	91	29	12
30	163	166	176	165	146	117	94
48	287	352	282	375	424	210	253
68	345	337	443	521	628	394	347
82	246	363	383	561	572	414	435
101	142	356	317	611	547	511	519
			SOUTHERN CONDITIONS				
18	40	39	31	29	59	37	12
30	112	101	95	89	120	61	52
48	119	124	142	200	163	194	109
68	131	121	190	225	170	208	211
82	15	37	150	277	96	297	218
101	—	14	68	166	27	226	210

varieties. Under northern conditions vegetative weight had not decreased much as late as 101 days after emergence of late varieties.

The stolon growth of the northern plants exceeded that of southern plants three to ten times at all times, because of the greater length of stolons, the development of more lateral and branch stolons and in longer life of the tuber-bearing stolons as you will notice in figure 2.

FIG. 2.

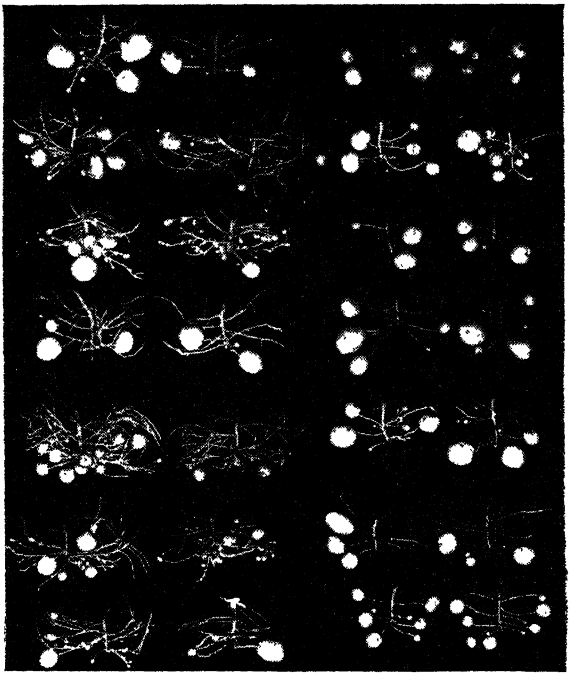

FIG. 2. Stolons and tubers on typical plants harvested on January 7, 1937, 68 days after emergence, from each variety as grown under "northern" and "southern" conditions. Plants at left produced with "northern", those at right with "southern" conditions. Varieties from top to bottom are: Warba, Triumph 12, Irish Cobbler, Chippewa, Triumph 23, Katahdin, and Russet Rural.

With "southern" plants tubers were differentiated quickly and 15 to 30 days earlier than with northern plants that differentiated more tubers during a longer time, (Fig. 2, table 2). Under both conditions the maximum numbers of tubers were attained about the time of maximum vegetative weight. When plants became senile and the vegetative weight decreased, the total number of

TABLE 2.—*Mean number of tubers produced per plant by each variety under "northern" and "southern" conditions*

Days after Emergence	Warba	Triumph 12	Irish Cobbler	Chippewa	Triumph 23	Katahdin	Russet Rural
			NORTHERN CONDITIONS				
18	9-0[1]	0	0	0	1.0-0	0	0
30	10-0	10-0	0	3.7-0	6.3-0	0	0
48	13.7-1.3	32.7-0	12.7-0	14.3-0.3	25.0-0	0.7-0	0
68	8.7-2.0	31.7-2.0	36.7-0.7	12.0-1.3	41.0-1.0	27.3-0.7	10.0-0.7
82	19.3-1.7	45.7-1.7	23.7-1.3	21.7-2.0	56.7-2.0	25.0-1.7	20.0-1.3
101	7.7-3.0	57.8-3.0	30.0-2.7	23.7-3.0	28.0-1.7	16.0-3.0	18.3-1.7
134	3.7-2.3	18.0-3.0	33.0-3.3	37.0-5.6	11.0-4.3	38.3-6.0	36.7-4.0
			SOUTHERN CONDITIONS				
18	4.0-0	3.3-0	1.7-0	2.3-0	2.3-0	0-0	1.7-0
30	6.3-0	14.0-0	5.7-0	7.0-0	9.7-0	6.0-0	2.3-0
48	6.0-2.0	12.7-1.7	5.3-0.7	6.3-1.3	16.0-1.7	6.7-0.3	8.0-1.7
68	7.7-3.0	13.3-3.3	6.3-2.0	7.7-2.0	14.7-2.3	7.7-2.3	8.0-2.0
82	4.0-2.0	7.7-1.7	8.3-2.3	7.0-2.3	17.3-3.3	18.3-2.3	7.3-2.0
101	4.0-1.7	6.0-3.0	7.3-2.3	8.7-4.0	8.3-3.0	10.0-4.3	10.1-2.7

[1]First number is mean total number of tubers per plant, second number is mean number of tubers weighing more than 25 grams each.

TABLE 3.—*Mean weight per plant (in grams) of tubers produced by each variety by various numbers of days after emergence when grown under "northern" and "southern" conditions*

Days after Emergence	Warba	Triumph 12	Irish Cobbler	Chippewa	Triumph 23	Katahdin	Russet Rural
			NORTHERN CONDITIONS				
18	0.1	0	0	0	0	0	0
30	2	2	0	2	3	0	0
48	85	54	9	53	10	8	0
68	215	122	83	173	111	71	51
82	237	218	176	231	213	253	146
101	255	320	293	534	392	259	323
134	386	467	460	653	387	471	479
			SOUTHERN CONDITIONS				
18	1	0.3	0	0.3	0.3	0	0.7
30	36	20	10	3	21	7	4
48	103	101	60	79	118	43	9
68	182	210	122	106	169	155	110
82	142	187	170	247	266	172	111
101	145	204	202	305	253	235	213

tubers decreased but the decrease was greater with northern than southern plants. Under both conditions the total number of tubers produced by the Chippewa and Russet Rural increased until the end of the season.

Early in the season size and total weight of tubers increased much more rapidly under southern than under northern conditions. However, the maximum weight of tubers was greatest with northern plants. For tuber production, southern plants were considerably more efficient than northern plants as shown by the consistently higher ratios of weight of tubers to that of tops as observed in table 4.

Comparative Response of Early and Late Varieties

Under northern conditions, which were favorable for vegetative growth in the early part of the season and unfavorable for carbohydrate accumulation (but with gradual reversal as the season advanced), the vegetative weight of the early varieties reached late mid-season maxima and then decreased, whereas the vegetative weight of the late varieties increased more slowly attaining the maxima later. These facts suggest that the late varieties may have higher respiration rates than the early varieties. The late season increase in stolon growth and differentiation with that of numerous tubers by late varieties indicates a type of plant that can continue considerable vegetative growth and carbohydrate accumulation simultaneously. This type of plant is not characteristic of the early varieties. The late varieties eventually produced a greater weight of tubers per plant than the early varieties, but never became as efficient—always having had lower tuber / top ratios.

Under southern conditions, which were more favorable for carbohydrate accumulation than for vegetative growth in the early part of the season (tending toward a reversal as the season advanced), the vegetative weight of late varieties continued to increase two or three weeks longer than that of early varieties. Both early and late varieties experienced a decrease in vegetative weight at the close of the season, indicating that both types had reached maturity. Although the differences beteween varieties, with regard to time and early tuberization, were less than under northern conditions the early varieties had most total tuber weight per plant until after mid-season, but eventually there was little difference.

TABLE 4.—*Ratios of fresh weight of tubers to fresh weight of tops produced by each variety by various numbers of days after emergence under "northern" and "southern" conditions*

Days after Emergence	Warba	Triumph 12	Irish Cobbler	Chippewa	Triumph 23	Katahdin	Russet Rural
			NORTHERN CONDITIONS				
18	.04	0	0	0	0	0	0
30	.01	.01	0	.01	.02	0	0
48	.30	.16	.03	.14	.03	.04	0
68	.62	.36	.19	.33	.18	.18	.15
82	.96	.61	.46	.41	.37	.41	.27
101	1.80[1]	.90	.92	.88	.72	.92	.62
			SOUTHERN CONDITIONS				
18	.03	.10	0	.01—	.004	0	.04
30	.33	.20	.10	.03	.18	.11	.08
48	.92	.82	.43	.39	.72	.22	.79
68	1.39	1.74	.64	.92	1.00	.74	.52
82	9.34[1]	4.02	1.11	.89	2.76	.58	.51
101	—	14.57	3.00	1.84	9.39	1.04	1.01

[1]Very high ratios at end of season are due to senility of tops, many leaves being dead.

With the early varieties the maximum vegetative growth was approximately only one-third as great under southern conditions as under northern, but with the late varieties the southern plant tops weighed approximately one-half as much as under northern conditions. Despite the relatively much smaller tops of the early varieties and enhancement of tuberization in late varieties by the favorable southern environment, the early varieties were still the most efficient tuber producers as shown by the constantly higher tuber / top ratios.

Response of Individual Varieties

Measured by earliness or tuber/top ratios the Warba was the most efficient tuber-producing variety. Under both conditions it produced more weight of tubers per plant than any other variety. Commercially the tuber yield could be improved with this variety by closer planting. For the production of early potatoes the superiority of this variety was less pronounced under southern than under northern conditions. The early strain of Triumph (T12) was second in earliness, appeared capable of producing a greater weight of tubers under both conditions than Warba, but always had a lower tuber/top ratio.

The response of the late strain of Triumph differed somewhat from that of the early strain, yet it did not always respond as did the other late varieties. It had the most abundant stolon growth of all varieties grown. The maximum vegetative weight and number of tubers was greatest of all varieties under northern conditions, but unlike the other late varieties both of these declined late in the season. It was less efficient than the other late varieties in producing tubers under northern conditions as shown by lower tuber/top ratios and lower final yields of tubers. It was influenced more by the southern environmental conditions than the other late varieties since it produced smaller tops, exhibited a greater capacity to set early tubers, had more tubers differentiated but fewer retained and had a higher tuber/top ratio.

The Irish Cobbler responded in an intermediate manner. Under northern conditions the vegetative growth rate and decline were relatively slow. The stolon system was similar to that of some of the late varieties. Tuber differentiation occurred relatively slowly, the number of tubers increasing until the end of the season as with the late varieties. The early growth rate of tubers was less rapid but the late rate was more rapid than with Triumph 12 or Warba. The tuber/top ratio was always higher than with late varieties but lower than with the early

ones. This variety seems to have been unable to set tubers during the long warm days early in the season, but it appears to have been able to respond to later more favorable conditions in a manner similar to the late varieties. Possibly the genetic limitation of the life span prevented a late season performance equal to that of the late varieties. Under southern conditions the Irish Cobbler responded in an intermediate manner with regard to most characteristics.

Vegetatively the Chippewa performed as a late variety but under northern conditions it produced tubers earlier than the Irish Cobbler with the highest yield of any variety after the 82d day. It produced tubers at a relatively high rate per day throughout the entire tuberization period. Under southern conditions it showed the vegetative character of a late variety, but produced tubers over a longer period of time with the highest total yield of all varieties. Because of earlier tuberization and greater final yield it appears more desirable under southern conditions than the Katahdin. The primary stolons of the Chippewa were longer than those of any other variety but many good-sized tubers were borne on branch stolons.

The early vegetative growth of the Russet Rural was always slow. It was least efficient in producing tubers as indicated by low tuber / top ratios. Although it initiated tubers very late under northern conditions, tubers were found almost as early under southern conditions as with the earliest varieties. In view of the customary short stolons on this variety those produced in this experiment were unusually long.

Summary

For the purpose of determining adaptability and nature of response of varieties when grown in widely differing latitudes, two strains of Triumph potatoes and five other varieties were grown in the greenhouse under day length and temperature conditions simulating those that occur in the gulf coast ("southern") and those occurring in northwestern Nebraska ("northern"). Potatoes were harvested at intervals to determine the morphological development throughout the life period.

With all potato varieties tested under "northern conditions" in contrast with "southern conditions" maximum vegetative growth was greater and continued later into the season, stolon growth was much more extensive, tubers developed later and in greater numbers with greater total weight, but ratios of weight of tubers to that of the tops were lower.

The early varieties were able to develop larger vines and more tuber weight early in the season under northern conditions while days were still hot and long than could the late varieties which responded better to the cool short days late in the season.

The "northern" type of environment permits the manifestation of more varietal differences than does the "southern" type.

When judging tuberization efficiency by ratios of green weights of tubers to tops, the early varieties appeared more efficient than the late ones under both conditions.

Stolon growth and numbers of tubers set were increased to a very much greater extent under northern than under southern conditions with the Triumph than with any other variety.

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POTATO VARIETIES RECENTLY INTRODUCED TO GROWERS

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The varieties of potatoes that have been distributed to growers within the past ten years, as the result of the work of the National Potato Breeding Program carried on cooperatively between the U. S. Department of Agriculture and about 30 State experiment stations, are being rapidly increased. Approximately 37 per cent of the certified seed in Maine in 1941 consisted of four new varieties, namely, Katahdin, Chippewa, Sebago, and Houma. Small lots of Earlaine No. 2, Mesaba, Pontiac, and Sequoia were also on the certified list. About 1,300 acres of new varieties were certified in Minnesota. Among these varieties are the Warba, Red Warba, Mesaba, Chippewa, Katahdin, Houma, Pontiac, Sebago, and Sequoia. Nearly all the certified potatoes in North Carolina were of the Sequoia variety—approximately 11,000 bushels. In New York state the Katahdin, Chippewa, Houma, Sebago, Mesaba, and Earlaine No. 2 have been certified; in Pennsylvania, Certified Nittany Cobbler and Pennigan are produced by a number of growers; whereas the Pontiac, Chippewa, and Katahdin are produced in Michigan; and in Wisconsin the Chippewa, Katahdin, and Sebago. It is evident, from the foregoing, that the new varieties are quite widely distributed and that seed can be obtained from a number of different sources.

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The U. S. Department of Agriculture has no seed stock of these varieties either for free distribution or for sale, but it should be possible to purchase such stock from any reliable seed dealer and especially from seed dealers in states where the certified seed is grown.

A variety of potatoes that does well in one section may be of little value in another. Don't buy high-priced seed because it is new or is superior in some other section without first finding out if it is adapted to your conditions. See your local county agent or write to the agricultural department of your state college or university. In many cases they may have made comparative tests of the new varieties and can give information regarding their behavior in the various sections of your state. In some instances they may be able to give you information on sources of seed. If they have not tested the variety in which you are interested, it is advisable to buy a small amount of seed stock and test it in comparison with your standard varieties.

CURRENT CONTRIBUTIONS ON POTATO INSECTS

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This review will be necessarily confined to a survey of the potato insect investigations being conducted in this country. Foreign accounts are few since a mere smattering of foreign journals and papers has been received during the past year. However, the large number of contributions appearing in our own literature should make the review worthwhile. It is the writer's opinion, based on past reviews, that potato growers in this country are troubled with most, if not all, of the potato insect pests.

A general idea of the number of these pests, their distribution and abundance may be obtained from the Insect Pest Survey Bulletin (30) published by the Bureau of Entomology and Plant Quarantine. Popular, well illustrated accounts of potato insects, such as farmer's bulletins, are issued from time to time by the Federal and State Agencies. Two of these general bulletins were issued by Iowa (13) and Colorado (5) on the potato insects occurring in those states. Other bulletins on a specific pest will be discussed under the insect concerned.

Colorado Potato Beetle, *Leptinotarsa decemlineata*

Aside from the infestation records published in the Insect Pest Surveys and the general bulletins mentioned no detailed consideration was given to this old and familiar pest.

POTATO FLEA BEETLE, *Epitrix cucumeris*

The potato flea beetle is distributed over the United States in most of the potato-producing regions. The beetles or adult forms feed on the foliage producing the well known "shot hole" appearance and the larvae or immature stages cause certain tuber disfigurations called "tracks" and "slivers". The latter injury in some sections is more serious than the foliage injury.

Anderson and Walker (1) have summarized a nine-year study of the flea beetle in eastern Virginia and have discussed life history, damage and control. For the Eastern Shore a 4-6-50 Bordeaux spray with two pounds of calcium arsenate added has given substantial yield increases and is recommended. The yield increases obtained from spraying have been proportional to the density of flea beetle infestations. Other pests were virtually absent during the years of the study. In central New Jersey, as a result of several experiments, Daines and Campbell recommend a single strength 5-5-50 Bordeaux schedule for Cobblers. Bordeaux has also been found effective in Iowa (13) and in Massachusetts (2). The use of zinc arsenite for flea beetle control is recommended to growers in Nebraska (31) and Colorado (5).

For Long Island, Skaptason and Blodgett (27) have found rotenone in either dust or spray form useful as a supplement to copper fungicides and it has been suggested as an alternative to Bordeaux where this spray does not seem to increase yields. In a preliminary report by Heuberger and Diamond (10) the use of derris, a rotenone-bearing powder, was found to enhance the control of *Alternaria* blight by neutral copper presumably by reduction of flea beetle injuries. The fungus is a wound parasite and flea beetle punctures may provide an entrance for infection.

POTATO LEAFHOPPER, *Empoasca fabae*

The old and interesting problem of the nature of leafhopper injury has been reinvestigated by Medler (14) using alfalfa, a common host of this insect. He made a detailed histological study of injured plant materials and observed in particular the reaction of the cells near the puncture sheath. The sheath material is probably a salivary secretion injected into the plant tissues at the time of feeding. That this secretion contains a toxin is indicated by cellular reactions such as nuclear abnormalities and cell degeneration in the vicinity of the sheath.

The control of potato leafhoppers by spraying and dusting is commonly recommended where the pest is serious. In Wisconsin (34) where leafhoppers are usually abundant a 5-5-50 Bordeaux has increased

yields by 40 to 60 bushels in three years of comparative tests. The use of pyrethrum and sulfur dusts has given good control on Long Island but pyrethrum is the only one that has increased tuber yields (27). Watkins (32) found from laboratory tests that pyrethrum was exceedingly toxic, whereas derris and Bordeaux were inferior as contact poisons.

A very interesting problem, that of breeding potatoes resistant to potato leafhoppers, has been tackled by Sleesman and Stevenson (28). In the preliminary stages of this work difficulties were encountered in obtaining a good criterion for the degree of resistance. Nevertheless, a few seedlings showed some resistance or tolerance to leafhopper attack when compared with standard varieties.

Potato Aphids

Potato aphids have been notorious because of their role as vectors of virus diseases. Simpson (24) made an extensive study of aphids and their relation to the spread of potato virus diseases in Maine. This investigation indicates the need for a foundation seed stock program and emphasizes the need for intensive roguing and isolation to prevent spread of virus diseases. Further, Simpson (25) (26) attempted to prevent the dissemination of disease by the use of insecticides for aphid control. Although spray applications reduced aphid populations no reduction in virus disease content of the tubers taken from sprayed plots was obtained.

Heavy aphid infestations, principally of the aphid, *Macrosiphum solanifolii,* are frequently encountered in potato plantings on Long Island. Since this region produces very little seed stock, interest is in the value of aphid control for increased yields. The use of nicotine as a spray or vapor was found, by Nottingham and Rawlins (19), to give excellent aphid kills and to increase substantially the yields of treated plots.

The sudden appearance of aphids in potato fields and the rapid buildup of infestations have been subjects of frequent observation. Gorham (8) noted mass flights of aphids during early August in New Brunswick and found shortly thereafter heavy infestations in potato fields. His observation was interesting in that massed flights of two species, *Myzus persicae* and *Macrosiphum solanifolii* occurred simultaneously.

Potato and Tomato Psyllid, *Paratrozia* sp.

The psyllids are known to occur only in the states west of the Mississippi. The feeding injury causes a stunting and yellowing of affected plants, hence the name "psyllid yellows". Edmundson (6) found that the vigor of seed stocks produced from heavily infested plants

was less when measured by productivity, than stocks from clean or moderately infested plants.

Sulfur either as lime-sulfur or the wettable forms is recommended for psyllid control (5)(31). Riedl (21) conducted comparative tests in Wyoming and found lime-sulfur slightly more effective than a wettable sulfur. Dusts containing sulfur, when properly applied, gave excellent protection from the psyllids.

WIREWORMS

Wireworms are the most important of the tuber pests in this country and are common to most potato growing regions. There are many species of economic importance only a few of which are abundant in any one particular region. It is most interesting to note the marked differences in life histories of the various species and the recommended measures of control.

Wireworms are a serious menace to the food and grain crops in England as indicated by a very complete survey made to determine wireworm distribution, population density and resultant injury. Finney (7) summarized the survey records using appropriate statistical procedures. The analysis is interesting and should prove valuable for other workers conducting similar surveys. Munro and Telford (17) presented data to show the relation of wireworm population to tuber injury in North Dakota. Pepper (20) also made a survey in potato fields of New Jersey where the eastern field wireworm *Limonius agonus,* is prevalent.

Stone (29) summarized a detailed study of the life history of the sugar beet wireworm in a technical bulletin. This wireworm is a common and injurious pest of potatoes and vegetables. Lane (11) has offered growers in the Pacific Northwest a bulletin on control of wireworms on irrigated lands. Preliminary studies on the corn wireworm, *Melanotus communis* have been reported by Wilson (35)(36) from the Everglades region of Florida.

Considerable stress is placed on investigations of cultural practices and rotations for the control of wireworms since chemical treatment of the soil is not practical in potato production. Morrill and Lacroix (15) found that naphthalene in sufficient quantities reduced population but was too expensive to be recommended. Lane *et. al.* (12) reported that an experiment of long standing showed differences among infestations in the various crops grown in the irrigated section of the Northwest. Populations in sugar beets, corn and alfalfa were low whereas those in potatoes and wheat were high. A similar experiment in Idaho conducted by

Shull and Shirck (23) has shown that alfalfa reduced the wireworm population due perhaps, to poor survival of first year wireworms in this crop. Five years' results of potato rotation experiments conducted in two regions of New York were published by Nash and Rawlins (18). They found that infestations of the wheat wireworm *Agriotes mancus*, were heavy in rotation systems which included a two-year sod crop. In short rotations wireworms were scarce and caused negligible damage.

The ability of wireworms to withstand cold weather of Northern climates is confirmed by Munro and Telford (16). In North Dakota where air temperatures reach extreme lows the prairie grain wireworm survived equally well at depths varying from 4 to 21 inches in the soil.

MISCELLANEOUS

The question of the role of insects in pit scab was investigated by Granovsky and Peterson (9). They found that scab lesions were invaded by secondary saprophytic organisms which cause decay. Mites, collembola and scab gnats invade the resulting pits and feed on the decaying material. Mites were also found by Ruehle (22) to be associated with seed piece decay.

Watkins (33) published a bulletin on the life history and control of the clover leafhopper *Aceratagallia sanguinolenta* a vector of potato yellow dwarf. This work was done in western New York where yellow dwarf has been a problem to seed growers.

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SOME POSSIBILITIES OF THE IRISH POTATO IN NORTH ALABAMA

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The development of a fall potato program in North Alabama is part of a broad potato program for the state. The place which North Alabama occupies in the state's plan can, therefore, probably best be understood by outlining the general features of the state's program. As a prelude to a statement of the potato program for the state two facts should be pointed out: (1) approximately 95 per cent of the present commercial potato crop originates in three South Alabama counties; (2) probably 98 per cent of the seed for this acreage originates outside the state.

In attempting to outline, about ten years ago, a comprehensive, long-time, state-wide potato program and formulate plans for developing the program it was recognized that at least four rather distinct phases needed attention. They were: (1) field studies in South Alabama on production problems of the commercial potato growers; (2) testing and certification of out-of-state seed with performance in the South as a primary requisite; (3) development of new outlets for the commercial potato crop; and (4) possibilities of seed production in the state.

Certain phases of the production and seed testing program have been reported during the past three years (1, 2, 3, 4, and 5). Nothing has been reported on the other two phases of the program.

The cost of seed for the commercial growers of the state is so large as to make this item of major importance. Seed purchased outside the state cost Alabama growers four hundred thousand dollars in 1940. In casting about for possible means of producing within the state at least part of the seed requirement for the South Alabama commercial spring crop three courses appeared open: (1) use of seed from the South Alabama spring crop of the previous year carried over in cold storage; (2) use of fall-grown seed produced in South Alabama from the South Alabama spring crop; (3) use of North Alabama fall-grown seed produced in turn from the South Alabama spring crop.

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For years it has been apparent that North Alabama had certain promising but undeveloped possibilities in potato production. The production of fall potatoes in North Alabama especially offered interesting possibilities. First, it offered an outlet as seed for graded and certified No. 2 potatoes from the South Alabama commercial crop, thus creating an outlet for this grade of potatoes; second, it offered the possibility in North Alabama of an industry itself engaged in producing seed for the commercial spring crop of South Alabama. There were two other possibilities in the development of an expanded North Alabama fall potato acreage: (1) production of potatoes to supply table stock for local and state-wide needs during the winter and spring months; (2) production to supply seed needed locally and for the general spring crop of the state. Two facts were of special importance in this respect: (1) unloads of potatoes in Birmingham alone during the period from October to May, inclusive, total approximately 90 cars per month; (2) the great bulk of seed potatoes planted in small quantities for home use throughout the state, just as for the commercial crop, comes from sources outside the state

It is obvious that four points had to be established experimentally before the several phases of a North Alabama program, envisioned in these possibilities, could be passed on as recommendations to farmers in North Alabama: (1) the value of the North Alabama fall-grown potato as seed for the South Alabama commercial spring crop; (2) the value of the South Alabama spring-grown seed for the North Alabama fall crop; (3) the production possibilities of North Alabama fall potatoes as a cash crop; (4) the value of the North Alabama fall-grown potato as seed for the general spring crop of the state. A considerable amount of experimental data has been accumulated during the past five years on these points.

Value of North Alabama Fall-grown Seed for the South Alabama Spring Crop

Seed produced on experiment stations

In 1935, a cooperative experiment was started between the two North Alabama substations, one located at Crossville on Sand Mountain and the other at Belle Mina in the Tennessee Valley, and the South Alabama substation at Fairhope. The principal purpose of the experiment was to determine the relative value of seed from the North Alabama fall-grown crop and northern-grown certified seed for the South Alabama spring crop.

In table 1 are given the yields of potatoes at Fairhope in the spring

of 1937 with seed from different sources. The check represented seed certified in North Dakota in 1936. The other seed lots had been grown in Alabama since 1936 or longer.

The two seed lots for treatments 3 and 4 and for 5 and 6 which had been carried through two successive crops in the South and the seed lot for treatments 1 and 2 which had been carried through at least four successive crops in the south when carried in cold storage produced yields as high as certified seed direct from a northern state when all were grown experimentally in 1937 in South Alabama in the commercial potato section.

In table 2 yields are given for the 1937 spring crop in South Alabama for different lots of certified seed direct from Minnesota, North Dakota, and Wisconsin, and the yields for the same lots as a fall crop in North Alabama and as a spring crop the following year both in South Alabama and North Alabama.

There is nothing in the yield of potatoes in South Alabama in 1938 to indicate that seed coming from the South Alabama spring crop planted in North Alabama in the fall and back to South Alabama in the spring are less productive than seed direct from western or northern states. Seed lots multiplied through two crops the previous year in the south produced equally as well in South Alabama as the check from certified seed direct from Nebraska. It is of interest to note that there was a wider spread in the yields of the different lots in 1937 from certified seed direct from the seed-producing states than in 1938 from the seed which had passed through two crops the previous year in the South.

In table 3 are given the yields of potatoes in South Alabama in 1938 from certified seed obtained in 1936 from 10 different growers representing three seed-producing states. These seed lots were multiplied as a spring crop in South Alabama and as a fall crop in North Alabama in 1937 and then used as seed the following spring in South Alabama together with seven other seed lots coming directly from four other seed-producing states.

Again seed which had been multiplied through a South Alabama spring crop and a North Alabama fall crop were just as satisfactory as seed direct from the western or northern seed-producing states and again there was equally as wide a spread in the yield of potatoes in South Alabama from certified seed direct from the seed-producing states as there was from the seed twice multiplied in the south.

Seed produced by farmers

The records in tables 1, 2, and 3 were obtained from seed produced at experimental substations. To determine the value of North Alabama

TABLE 1.—*Yield of marketable spring potatoes in South Alabama with seed from North Alabama fall potatoes produced on Sand Mountain. Triumph variety*

Bushels per Acre

	Before 1936			1936		1937
Treatment	History of Seed	Place of Spring Crop	Storage	Place of Fall Crop	Storage	Yield South Ala. 1937
1	Produced S. Ala. prior to 1935	S. Ala.	Cold	Sand Mt.*	Cold	154.8
2	" " " " " "	" "	"	" "	Home	114.9
3	Nebraska Certified "	" "	"	" "	Cold	164.3
4	" " "	" "	"	" "	Home	133.3
5	Minn. Certified "	" "	"	" "	Cold	146.2
6	" " "	" "	"	" "	Home	109.0
7	Check—N. Dak. Certified 1936	direct				145.8

*Hartsells sandy loam soil at Sand Mountain Substation.
Difference of 38.8 bushel per acre necessary for significance at 5% level.

TABLE 2.—*Yields of successive crops of potatoes in North Alabama and South Alabama. Triumph variety*

Source of Seed 1936	Yield South Alabama Spring 1937	Storage between S. Ala. and N. Ala.	Yield North Ala.** Fall 1937	Storage between N. Ala. and S. Ala.	Yield South Ala. Spring 1938	Yield North Ala. Spring 1938
	Bushels Per Acre Marketable Potatoes					
Minn. Cert.—No. 1	140.0	Home	79.8	Home	175.7	119.2
" " No. 1	140.0	Cold	219.8	Cold	190.2	137.5
" " No. 2	129.6	"	198.9	"	174.5	106.3
N. Dak. Cert.—No. 3	144.6	Home	260.0	Home	175.2	—
" " No. 3	144.6	Cold	147.2	Cold	173.8	131.3
Wis. Cert. —No. 4	176.1	"	171.4	"	173.8	103.3
Minn. Cert.—No. 5	189.2	"	***	Home	174.1	—
" " No. 6	120.6	"	***	"	187.0	—
" " No. 7	149.5	"	***	"	147.0	—
" " No. 8	182.0	"	***	"	187.9	—
" " No. 9	180.3	"	***	"	162.7	—
Check* direct	178.7*	Direct	***	—	180.3*	156.4
Nebr. Cert.				Direct		95.9

*Check was North Dakota Certified seed in 1937 and Nebraska Certified seed in 1938.

**Fall crop grown at Tenn. Valley Substation, Belle Mina, on Decatur Clay soil; the spring crops grown at the Gulf Coast Substation, Fairhope, on Norfolk sandy loam.

***Grown as unit in North Alabama but no yield records obtained.

TABLE 3.—*Yield of spring crop in South Alabama from North Alabama fall-grown seed and other seed direct from seed-producing states. Triumph variety*

History of Seed				Yield Spring Crop South Alabama
1936		1937		1938
State	Grower	Spring	Fall	Bushels Per Acre
Minn. Cert.	1	S. Ala.	N. Ala.	174.2
" "	2	" "	" "	134.4
" "	3	" "	" "	187.0
N. Dak. Cert.	4	" "	" "	173.9
Minn. Cert.	5	" "	" "	175.8
" "	6	" "	" "	147.0
" "	7	" "	" "	188.0
" "	5	" "	" "	196.0
N. Ala.		" "	" "	182.2
N. Dak. Cert.	4	" "	" "	175.6
Wis. Cert.	8	" "	" "	156.8
Minn. Cert.	9	" "	" "	174.5
" "	10		" "	181.9
	11		Colo. Direct	191.9
	12		" "	181.1
	13		" "	176.1
	14		" "	182.8
	15		Ind. "	142.3
	16		S. Dak. "	214.7
	17		" " "	199.7
		Check	" " "	180.3

Difference of 16.88 bushels per acre necessary to establish significance at the 5% level.

Spring crops grown at the Gulf Coast Substation; the fall crop grown at the Sand Mountain Substation.

seed as produced and handled by farmers, experiments were conducted in the fall of 1938 and 1939 in North Alabama with cooperating farmers. The yields of potatoes in South Alabama the following spring are given in table 4. Certain other seed lots coming direct from the seed-producing states were included for comparison.

Performance of the North Alabama fall-grown seed from practically all of these lots has been entirely satisfactory and the yields have compared favorably with the yield of check lots or of different seed lots direct from northern or western sources. The data continue to show a range of yields for the southern-grown seed with a more narrow spread

and a more uniformly high yield than different lots of certified seed direct from the usual seed-producing sates.

The yields of the southern grown lots in 1940 compared well with the check, some lots yielding more and some less. In the 1939 series it happened that no southern-grown lot yielded as high as the check; it might likewise be noted that none of the five strains coming direct from seed-producing states included in the test produced as much as the check. It should, however, be stated that in all ex-

TABLE 4.—*Yield of marketable potatoes in South Alabama with seed from fall-grown potatoes produced by N. Alabama farmers and with seed from other sources. Triumph variety*

Fall 1938 History of Seed			Produced by Grower	Spring 1939 Bushels of Marketable Potatoes—South Alabama
North Alabama		Fall-grown	1	203.5
"	"	" "	2	225.3
"	"	" "	3	156.2
"	"	" "	4	181.7
"	"	" "	5	170.0
Nebr.	Lot 1	Direct*	—	176.7
"	Lot 2	" *	—	148.8
"	Lot 3	" *	—	227.8
"	Lot 4	" *	—	170.5
"	Lot 5	" *	—	149.8
Check		"	—	236.8

Fall 1939				Spring 1940
North Alabama		Fall-grown	6	190.9
"	"	" "	7	201.2
"	"	" "	8	219.5
"	"	" "	9	168.5
Nebraska	Lot 6*		Direct	175.77
"	Lot 7*		"	232.8
North Dakota		Check	"	207.3

*These seed lots along with the checks were direct from seed-producing states. Other seed came from a Wisconsin certified lot, planted in South Alabama in the spring crop of 1938.

The North Alabama fall-grown seed were home stored until shipped to South Alabama in February.

Difference of 31.1 bushels per acre necessary for significance at the 5% level.

periments as far as possible potentially high yielding lots, as determined by past performance records in the south, have always been chosen as checks. Thus in the certification trials in 1939, involving 13 tiers each carrying approximately 30 seed lots in triplicate with 7 checks, the checks were the highest yielding lot in 5 tiers. Of 375 different lots tested in 1939, 48 yielded 20 to 30 bushels per acre below the check, 30 lots yielded 30 to 40 bushels, 52 lots yielded 40 to 60 bushels; and 55 lots yielded 60 bushels or more below the check. These lots represented in all cases, seed certified in the seed-producing state. It should, therefore, be obvious that the relative yield of tested lots with respect to the yield of the check is of less importance than the distribution of yields of one series of seed lots as compared with the distribution of yields of another series. It should be emphasized, however, that in practically all tests southern-grown seed have compared favorably with the high-yielding checks.

Value of South Alabama Spring-grown Seed for the North Alabama Fall Crop

Naturally, to establish the value of the North Alabama fall-grown potatoes as an excellent seed for the South Alabama spring crop would have little meaning in the mutual exchange of seed between the two sections unless it was also established that the South Alabama spring-grown potato makes a satisfactory seed for the North Alabama crop, and that the North Alabama grower might make the enterprise a profitable one.

Completed tests on these last two points are not so extensive as those on the value of the North Alabama fall-grown seed for the South Alabama spring crop. Extensive tests with farmers are now being conducted on a semi-commercial scale to determine the range of returns which might be expected from fall potatoes in North Alabama and to work out a large number of storage and cultural problems on which more information is needed.

In table 2, the yields are given for four certified seed lots purchased in 1936 from three different seed-producing states, grown as a spring crop in South Alabama and as a test crop in North Alabama in the fall. Although no check was used the yields were satisfactory. Yields of 80, 220, 199, 260, 147, and 161 bushels per acre were recorded for the several lots. Yields averaged in North Alabama higher than the yields in South Alabama for the same lots.

For many years on a limited scale North Alabama farmers have produced fall potatoes using seed from their own spring-grown crop, sometimes treated with ethylene chlorhydrin but as often untreated. Three years ago an Extension project was inaugurated to test out the feasibility of producing fall potatoes on a semi-commercial scale. Several observations have come from this project: (1) seed from the North Alabama spring crop have usually produced about 60 per cent the yield of South Alabama spring-grown seed; (2) as a whole the farmers have been satisfied with the venture although there have been many failures along with successes; (3) low rainfall in the fall months often limits yields.

The failure of some farmers and the success of others have emphasized the need for a thorough study of production problems of the North Alabama farmer and a study of storage problems involved in handling the crop between harvesting in South Alabama and planting in North Alabama. These are being studied at the present.

Results of a cooperative experiment with 9 farmers are given in table 5.

TABLE 5.—*Yield of fall potatoes in North Alabama as grown by cooperating farmers*—1940

Grower	Bushels per Acre Marketable* Potatoes
1	133.5
2	135.0
3	145.3
4	116.8
5	101.2
6	156.4
7	146.5
8	130.0
9	165.0
Average	136.7

*The average of duplicate plots for three good treatments in an experiment consisting of 19 treatments varying the size of seed, spacing of seed, rates of fertilizer application, types of storage and depth of planting.

Each of these 9 farmers was comparing 19 different treatments varied as to the size, spacing, and storage of seed, the rate and method of applying fertilizer and planting of the seed.

The average yield of duplicate plots consisting of these good treat-

ments was 136.7 bushels per acre of marketable potatoes; 165 bushels per acre was the highest yield and 101 bushels the lowest yield produced by any farmer on this basis.

These yields should be considered sufficiently high to offer satisfactory returns to farmers as a commercial venture.

Value of North Alabama Fall-grown Seed for the North Alabama Spring Crop

Some data are given in tables 2 and 6 to indicate that the North Alabama fall-grown seed is satisfactory for the North Alabama spring crop. There was only one actual yield record in table 6 although the approximations given indicate quite satisfactory yields. A yield of 206 bushels per acre for farmer No. 4 is well above a normal yield for the area. The yield of the check in table 2 was higher than any of the locally grown seed although again it should be emphasized that a check representing a single seed lot does not give a correct evaluation of different seed sources as already conclusively shown (5). The yield of the check in this test was considerably higher than the yield of the other seed lot which came direct from a seed-producing state; likewise, the yields of all seed lots from North Alabama fall-grown seed were higher than that of the other commercial lot included. Reports from farmers and observations indicate that the North Alabama fall-grown seed planted from the spring crop of South Alabama and used as seed for the North Alabama spring crop may be usually expected to yield 50 to 75 additional bushels of potatoes per acre than the seed which have been grown in the area for several years and to yield as well as, or better than, the commercial seed direct from seed-producing states. Adequate experimental data on these two points are lacking.

Value of Seed Grown Continuously in the South over a Long Period

It has been known that certain North Alabama farmers have been growing potatoes continuously for long periods. One lot was found which had been grown for at least 20 years in the South. Many such lots were collected and tested in 1936 in South Alabama against certified seed direct from a seed-producing state. It was found that practically all of the southern lots were affected with virus diseases and presented a rather weak appearance, although one lot gave a yield of 135 bushels per acre as compared with a yield of 145.8 bushels for the check.

No roguing had been done in these lots and the prevalence of virus diseases would naturally have been expected. Since one bushel of potatoes multiplied once in South Alabama and once in North Alabama will furnish approximately 80 to 100 bushels of seed for the following spring crop, there is really no special reason for trying to grow seed lots continuously in the South.

TABLE 6.—*Yield in North and South Alabama of seed twice multiplied in the state the previous year. Triumph variety*

Bushels per Acre Marketable Potatoes

North Alabama Grower Fall—1938*	Type of Storage between Crops	Yield in South Alabama Spring 1939	Yield in North Alabama Spring 1939
1	Cold	158.4	150 - 175*
1	Home	182.1	——
2	Cold	136.3	——
2	Home	152.5	——
3	Home	153.6	200+
3	Home	156.7	200+
4	Cold	154.5	206.0
Check	Direct	182.7	——

History—Certified seed planted as spring crop in South Alabama and as a fall crop in North Alabama, 1938; records are for spring crop in North and South Alabama in 1939.

A difference of 10.8 bushels per acre required for significance at 5% level.

*Estimates only, except for grower No. 4.

SUMMARY

The data which have been presented show: (1) that the South Alabama spring-grown potato makes an excellent seed for the North Alabama fall crop; (2) that the North Alabama fall-grown potato makes a very satisfactory seed for the commercial spring crop of South Alabama and also for the general crop in North Alabama; (3) that the production of a fall crop in North Alabama offers definite commercial possibilities. Further experimental work is necessary to determine the best methods of storage of seed between the South Alabama spring crop and the North Alabama fall crop, and between the North Alabama fall

crop and the South Alabama spring crop. More information is needed on production methods for the North Alabama crop. Experimental work on these points is being conducted at the present time.

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ERRATUM

On page 40 in the February issue, 1942, under "Literature Cited," the first reference should read, "Classification of tomato varieties according to physiological response."

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SELECTION OF PARENT SEED POTATOES

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An efficient selection of parent seed potatoes depends in some unknown degree on the hereditary factors governing their vegetative reproduction. The behavior of the descendants during several generations, when reproduced in commercial growing areas, is the only proof that an efficient selection of parents has been obtained. It is believed that the hereditary status of the potato is greatly influenced by the inter-mixture of descendants from mutant eyes. The problem is, can any improvement be made in the descendants from selected parent stock in yields, stolon development, tendency to second growth, vegetative cycle in vine, or resistance to bacteria, fungus or virus.

The geneticist clings strongly to the belief that under vegetative reproduction several of these factors cannot be controlled and that the pattern of the variety remains unchanged through unlimited generations of vegetative reproduction. There is little need to combat this theory except to say that it does not explain all the events that occur and if it is closely followed, the door is closed to possible improvement in the vegetative selection of parent seed potatoes.

Through genetic selection resulting in the creation of new varieties, some gains have been made in better yields, quality and resistance to biological enemies. But this is extraneous to this discussion and the problem of bacteria, fungus and virus is entirely omitted except to postulate that all parent seed stocks shall be as free from these organisms as it is possible to accomplish.

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In this discussion the field is narrowed to selection under vegetative reproduction from existing seed stocks for yield, shape and grade desirability in the descendants. This entails some knowledge of the hereditary behavior of the parents. The problem is complicated by the self-evident fact that environmental factors such as nutrients, moisture and climate involved in the growth of the descendants materially influence their physical qualities. It is always difficult to determine when yield, shape and grade desirability are the result of environmental conditions and when they are the result of inheritance. But to close ones eyes to a selection based on inheritance in vegetative reproduction is to foreclose a fertile field.

The present methods of parent seed selection used by most certified seed growers of bin or field selection reproduced from tuber indexed or seed plot origin, is almost worthless. Although these methods provide the means of a more or less inaccurate selection for freedom from virus infections, beyond this, they do not go, and present no suggestion for necessary improvements that are clearly indicated. The inaccuracies in these methods probably account in large part for the wide divergence in the performance of certified seed when reproduced in commercial areas.

Year to year selection of individual tubers, based on size or shape, or on any set of specifications, no matter how rigorous, leads to disappointing results. This method is better than nothing but it carries no hope of real improvement.

A decided improvement over methods that are recommended to certified seed growers has been made by family selection. A family started from one potato and increased several generations has provided, when properly handled and when the descendants are tested in the same areas where the seed is to be used for commercial reproduction, the means of controlling and eliminating virus and bacteria and also increasing yields by the elimination of families that are undesirable. It also provides the mechanism for the elimination of families that for some unknown reason, break down after several generations. The cause of the breakdown is probably present in the original parent of the family but the weaknesses do not become apparent until they have become intensified in succeeding generations and in the concentration of large numbers in a reproduction on a large area implicit in family reproduction. When this happens, the entire family can be eliminated but contemplate the impossibility of the elimination in a field of a large number of undesirable individuals which occur when selection of parent seed is made on a field or bin selection.

Family selection, irrespective of the values that have been realized, does not provide the means of eliminating from the family individuals whose descendants are undesirable. It is the purpose of this discussion to contemplate an approach to this problem. Little or no work of either a practical or critical nature has been attempted with the potato to determine its inheritance status under vegetative reproduction. Until something is known of the inheritance status of individual potatoes, it may be impossible to remove the undesirable individuals now to be found in all families. It therefore may be wise, in order to get some hint of procedure, to review the work of Jennings on the inheritance status of single cell animals to determine their inheritance status under vegetative reproduction. The hope is that from the methods used and the patterns developed in this work, some method of attacking the potato problem may be suggested. Of course, there is a great difference between the single cell Protozoa and the complex, highly organized potato, but there are also many points of similarity in their behavior which may suggest valuable improvements in potato selection.

The work referred to is "Hereditary Status of the Rhizopods" by H. S. Jennings, Professor of Zoology, Johns Hopkins University, Research Associate of the University of California at Los Angeles; in a paper read before the University of Pennsylvania Bicentennial Conference, 1941.

This paper is a study of the vegetative reproduction of one of the Protozoa which are microscopic animals whose bodies consist of single cells that reproduce, by the fission of the cell, into two or more individuals. The experimental work starts with the offspring from a single parent and is carried on through many generations. The reproduction is vegetative.

Jennings found that all the individuals derived from a single individual by vegetative reproduction (called a clone) retain as a whole their distinctive characteristics but that there is a difference between the clones. Also that among the individuals of the same clone there occur slight differences in their characteristics such as differences in size, in number of spines, in length of spines, and sometimes in the number of teeth surrounding the mouth. He found that in vegetative reproduction the different clones reproduce in their main features true to type with minor diversities among the individuals of each clone.

When a number of diverse individuals of a single clone are allowed to vegetatively reproduce separately and their descendants are com-

pared, even though the single individuals differ greatly, usually there is no indication of inheritance of the differences. If, from a single clone, there is bred from large individuals and separately from small individuals, it is usually found that both sets produce offspring of varying sizes, but that the average size is about the same in the descendants of both sets. The difference in size does not seem to be inherited. If descendants from individuals with few spines are compared with descendants of individuals with many spines, it is found that both sets of parents produce offspring with varying numbers of spines and that the average number of spines is about the same in the two sets, that is, the difference between parents does not seem to be inherited by their descendants.

But when breeding is continued for many generations and includes a large number of individuals of the same clone, it is found that these conclusions are not complete. There is found in such long continued breeding some degree of inheritance of the differences. When breeding for many generations only from individuals with long spines while breeding at the same time from another group exclusively from individuals with short spines, it is found after the lapse of numerous generations that the descendants of the long spine parents have, on the average, longer spines than the descendants of short spined parents. Thus it is found that the difference in length of spines is, in slight amount, in faint degree, inherited in vegetative reproduction.

The same result is reached if selective breeding is based on other characteristics such as the size of the shell, or the number of spines, or the number of teeth surrounding the mouth. In this way by selective breeding within the single clone, there were obtained by Jennings five hereditary diverse races or strains. These five different races have been derived from a single individual through vegetative reproduction. They continue to be diverse when vegetative reproduction is continued and the differences are hereditary.

Without going into the details of the experimental work, Jennings further found that inheritance occurs as if there were two factors at work. On the one hand there is the peculiar constitution of the individual parent, which in some way tends to give the offspring a constitution like itself. On the other hand, there is the constitution of the race as a whole, tending to make the offspring like the mean of the race. The resultant in the offspring is that they have but about one-third of the parent's peculiarities, regressing two-thirds towards the racial average.

Jennings found that by continued selection of individuals of a

certain type, in time a biotype of that kind is established. In inheritance there is not only a certain amount of regression towards the racial type but there is also inheritance of some portion of the parental peculiarities; inheritance of a part of the parental divergence from the racial type.

Jennings calls attention to an important feature of selective breeding in vegetative or uniparental reproduction. Such selective breeding does not cause the production of any types or characteristics that would not be produced by unrestricted multiplication without selection. It merely causes the omission of some of the intermediate types that would have been produced. If vegetative reproduction occurred without restriction and without selection, all the types that are produced under selection would still be produced; also many others. Therefore, the experiments show that the single clone gradually splits up into many hereditary diverse types by the methods described, namely, by the occurrence of variation in vegetative reproduction and by inheritance of a part of the diverse characteristics together with the partial regression to the racial type.

There remains an important question on which evidence exists. To what are the variations that occur in vegetative reproduction due, those that are inherited in the way just described? These variations are the primary feature in the differentiation that occurs; how are they brought about?

There is evidence that in some cases these variations are produced, or at least influenced, by environmental conditions. Such a case is seen in the inherited abnormalities of the shell in Arcella, studied by Jollos (1924). These are influenced in their frequency and extent by environmental conditions. They become more frequent and more marked when the animals are cultivated in a small amount of fluid, not frequently changed, so that there is an accumulation of excretory products. But even under these conditions the abnormalities are produced only in clones which have a constitutional tendency to produce abnormalities, as shown by the fact that a few abnormal individuals occur in them even under the best of conditions. But the number and degree of the abnormalities are greatly increased by breeding in old culture fluid.

Now, what is of much interest, the fixity in inheritance of the abnormal characters depends on the length of time that the reproducing clones are kept in the conditions that favor the abnormalities. The longer they have remained in the old culture fluid, the longer the abnormalities are inherited under reverse selection.

Returning to our discussion, there seem to be many points of sim-

ilarity in the vegetative reproduction of the Protozoa and the potato. In the non-selective vegetative reproduction of the Protozoa there are disclosed many individuals that deviate from the normal and it is difficult to demonstrate that there is any inheritance of differences. However, when selective vegetative reproduction is carried on in the Protozoa, there is demonstrated an inheritance of differences. The suggestion follows that by selection in the potato, inheritance of differences may be found.

The environment surrounding the growth of descendants in both cases materially conditions the descendants. There is a great deal of similarity between the two in this respect.

The separation of the Protozoa into clones with uniform inheritance status but with a difference in clones, that all originated from the same parent cell, may be suggestive in potatoes that lines or clones from mutant eyes may be different from lines from non-mutant eyes and that if selection is made on this basis, uniform potato clones can be isolated. It may be true in potatoes that when the mutants of the past have been eliminated and when mutants that occur in the future generations are removed, that a homogeneous line or clone in potatoes will result. The selection of lines or clones that are desirable can then be easily determined.

But whatever may be the similarity or difference between the Protozoa and the potato, the work conducted on and the pattern developed for, the Protozoa lends confidence to the thought that selection in the vegetative reproduction of the potato when properly performed has possibilities.

The ultimate goal in potato seed selection should be to establish a family that will, throughout succeeding generations, be highly uniform and have the desired characteristics in yield, shape and grade desirability when the seed is grown in an environment where the seed is used for commercial production.

At the present time all seed stocks of all varieties, including the new genetically created varieties such as the Katahdin, Chippewa, etc., as well as the old established varieties, give evidence in varying degrees of a wide difference between individuals. These differences are reflected in many ways and this very likely causes many of the disappointments realized by commercial seed growers. There is little need to enumerate these disappointments.

The first step in unscrambling the mixtures now found in all varieties of potatoes is to create families. This preliminary step will

eliminate virus and bacteria and tend towards a selection of parent stock that has desirable qualities.

The next step is to make, from desirable families, a selection based on the behavior of the descendants, of a large number of lines, each of which originates from a single eye. A separate harvest by hills of the first generation will result in the discarding of a large number of lines. The next elimination will be accomplished by growing a sample of the remaining, or chosen lines, in the commercial growing area and making proper eliminations from the evidence gathered. The remaining potatoes in each line that has survived both of these tests are then reproduced in the seed growing area. The planting of single eyes from this generation on a unit-line basis is indicated. The descendants from each hill are to be harvested separately and each hill is to be judged separately. Any hill that deviates from the established specifications must be eliminated. A sample from retained hills is again planted in the commercial growing area and the undesirable hills are eliminated by this test. The remaining potatoes in a retained line can then be grouped and planted as a family in the seed growing area.

All of the undesirable individuals in the newly created family may not have been eliminated but the job, if well done, will probably be very satisfactory for commercial seed requirements. Trial and experience may prove that individual eye reproduction of a greater number of generations may be necessary.

The family freed from undesirable individuals will of course, be subject in future generations to the development of mutants or undesirable individuals whose multiplication in time will again lead to the conditions that now exist and which were described above. The suggestion is that new lines must be started annually and the process of removing undesirable individuals repeated over and over. By the time these lines are clean enough and large enough to be classified into the family status it may be time to discard the family from which they originated.

It may be possible to introduce a short cut in the number of generations reproduced from individual eyes if it can be proven, by planting whole potatoes that the mutant eye, or eyes, in the potato will not reproduce. At the present time this is nothing much more than a hope; however, if this is the case, after removing from the lines those that have been discarded for cause, the reproduction in the second generation can be made by planting whole potatoes instead of individual eyes. To some extent this may lessen the expense and labor.

REPORT OF POTATO VARIETY NOMENCLATURE COMMITTEE

The U. S. Department of Agriculture has had the usual number of miscellaneous lots sent in for identification, and these were grown and studied during the summer of 1941 at Presque Isle, Maine, and for the most part will not be reported on until next year.

A sample of seed under the name of Seneca was sent in by Thos. J. Neefe, Coudersport, Pa. for trial. Mr. Neefe claims that the variety originated from a package of seed purchased from H. W. Buckbee, Rockford, Illinois. This variety undoubtedly belongs in the Rural New Yorker group.

We are indebted to Dr. Donald Folsom for tracing the origin of the variety Harmony Beauty. Reliable information indicates that it was originated by Alva Mitchell of Harmony, Somerset County, Maine, about 1880, from seed from a potato ball of unknown parentage. It was first known as the Mitchell potato. Later the name was changed to Harmony Beauty.

Dr. Julian C. Miller has again requested recognition of some definitions used to express certain terms used in an article published in the American Potato Journal, June 1940, Vol. 17:140-147, entitled "Relation of Some Growth Characters to Stoloniferous Conditions in Seedling Irish Potatoes." The plants studied were grouped into five types of stoloniferousness as follows:

1. Basal set. Setting of tubers very close around the basal end of the main stem with very short or no intervening stolons.
2. Tuberous. Only one tuber per stolon and no excessive stolon development.
3. Slightly stoloniferous. Some stolons bearing more than one but less than four tubers, and the presence of some excessive development.
4. Stoloniferous. Numerous small tubers produced, with some stolons bearing four or more, and decidedly overdeveloped system of stolons.
5. Completely stoloniferous. Very excessive stolon development to the exclusion of tuberization.

The Committee finds no objection to the use of these definitions.

After exhaustive study Dr. William Stuart has the following to present regarding the identity of the White Rose and American Giant varieties of potatoes:

In recent years students of the potato variety nomenclature have been repeatedly asked for information concerning the identity of the White Rose and American Giant potatoes. For the past decade or more, all sample lots of tubers submitted under these names to those in charge of potato varietal studies in the United States Department of Agriculture, as well as all sample lots produced by them for a critical comparison in the field, have been found to be identical in every respect. This conclusion at once raised the question whether they were identical when originally introduced. In order to determine this point, a rather exhaustive search of seed catalogues and farm journals has been made to determine, if possible, the date of origin and introduction of each. In view of the present importance of the White Rose variety from a commercial standpoint in California, and an increasing interest in it in other sections, it would seem desirable to record the data thus obtained, even though it does not clearly establish that the two so-called varieties were originally identical. The data, as will be noted, do clearly prove that the White Rose is mentioned in literature, at least insofar as it has come to our attention, 10 years earlier than the American Giant.

The first mention of the White Rose potato occurs in a note by Dr. F. M. Hexamer, published in the *Rural New Yorker*, Volume 23, page 157, 1871. In this note he states that handsome samples of the White Rose from Wisconsin were exhibited at the American Institute Farmers' Club (date not given). This variety was claimed to have been originated in Grant County, Wisconsin. In 1874 it was listed in the potato catalogue of B. K. Bliss & Sons, page 14. J. M. Thorburn & Co. in their 1876 catalogue, page 19, list Wainwright's White Rose and Young's White Rose. These two were also included in the 500 variety collection exhibited at the Centennial Exposition in 1876.

The first description of any sort that has come to our attention is that found in Frank Ford's 1881 seed catalogue, page 13. It is there stated to be a late-season variety; tubers large, long-round; eyes a little depressed; skin and flesh very white; foliage strong and healthy, very productive. Andrew's White Rose is mentioned in Volume 46 of *Cultivator and Country Gentleman*, page 227, 1881.

Naple's White Rose is mentioned in Volume 50 of the *Rural New Yorker*, page 202, 1891. In this reference it is claimed that the variety was originated by M. Eichberger of Naples, N. Y. It is described as

being intermediate in season of maturity; tubers flat-oblong; very few eyes; skin buff white; flesh dull white.

T. W. Wood & Sons in their 1902 seed catalogue, page 5, list Extra Early White Rose, which they claimed was originated in Aroostook County, Me. The tubers are stated to be similar in shape to the Early Rose.

In the 1903 potato catalogue of E. E. Parkhurst & Company, page 3, White Rose is claimed to be a sport of the Early Beauty of Hebron, originated by E. E. Parkhurst, Presque Isle, Me., in 1896, and introduced by that firm. The statement is made in Jerrard & Company's potato catalogue that the White Rose is similar to the Early Michigan.

Crumb's White Rose, listed in Johnson & Musser's 1904 seed catalogue, page 8, is accompanied by the following statement: "Although this variety has been favorably known here for several years there has been no reliable source of seed supply. Mr. Crumb has brought this variety to such a state of perfection that it will produce more than any other variety. [Under similar conditions]."

Moore and Simons in their 1906 seed catalogue, page 42, list the New White Rose, which they claimed was a seedling between the Early Rose and the White Star.

The following description made by Stuart in 1907 from decendants of White Rose seed stock procured from T. W. Wood & Sons in 1902 is thought to be of sufficient interest to be included in this report: "Plants medium to large. Stems moderately branched, stout, angular, winged, medium green, tinged with purple, nodes very slightly colored. Leaves medium in size, leaflets moderately smooth, somewhat crumpled. Flowers numerous, medium large, white. Tubers oblong to kidney shaped; skin dull white; eyes numerous, medium in size and depth; eyebrows moderately prominent and medium long; sprouts grow in dark, short, stout, some color in tips; flesh creamy white."

American Giant. Much less information is available concerning the American Giant. B. K. Bliss & Sons in their 1881 potato catalogue, page 11, state that it was originated in western New York and introduced in 1880. No information is given concerning its parentage. It is described as being one of the largest varieties in cultivation, with vigorous vines and unusually large tubers; with many eyes. Second early in season of maturity; about 2 weeks later than the Early Rose.

It is listed in Frank Ford & Son's 1885 seed catalogue, page 14, as a new late variety, producing long, irregular, and somewhat flattened tubers; skin white; eyes small and considerably depressed.

The following description was made by Stuart from plants grown

at the Vermont Agricultural Experiment Station in 1907 from seed obtained from the West Virginia Agricultural Experiment Station. The plants are large, vigorous, healthy and compact. Stems are medium-branched, stout, distinctly angular, winged and dark green; leaves large, and flowers white. The tubers are large, elongated, pointed and sometimes kidney-shaped; skin somewhat rough and russeted, and dull white; eyes many, small, shallow, and eyebrows long, not conspicuous.

From the above data it is evident that there is no reliable information concerning the origin of either the White Rose or the American Giant. Neither are the published descriptions accompanying their introduction, particularly that for White Rose, sufficiently informative to identify them with current seed stocks. The data do show conclusively that priority of name would seem to justify listing the present stock as White Rose rather than as American Giant.

Respectfully submitted,

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J. C. MILLER,
WILLIAM STUART.

December 19, 1941.

ACCURACY OF THE ULTRAVIOLET-LIGHT METHOD FOR SELECTING RING ROT FREE POTATO SEED STOCKS[1] [2]

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The ultraviolet-light method for selecting potatoes free from bacterial ring rot was developed at the Montana Agricultural Experiment Station and reported in April and in December 1940 by Iverson and Kelly (1, 2, and 3).

The authors did not present this method as a positive means of identifying the disease. They have, however, emphasized the dependa-

Acknowledgment: The writers wish to acknowledge the fine work of Mr. John Blanchard who, under the direction of Professor H. E. Morris of the Department of Botany and Bacteriology, made the bacterial tests necessary for this experiment. Thanks are also tendered to Dr. H. C. Kelley who assisted in setting up the experiment.

[1]Contribution from the Department of Horticulture, Montana Agricultural Experiment Station, Bozeman, Montana.

[2]Published as Journal Series Paper 160, with the approval of the Director of the Agricultural Experiment Station.

bility of the method for the selection of disease-free seed stocks. In ultraviolet-light, fluorescence appears in tuber tissue affected by the potato ring rot organism, and by eliminating all tubers which show fluorescence in the vascular areas, seed stocks free from bacterial ring rot can be developed. The tubers which are eliminated, however, may not always be infected with the bacterial ring rot organism since other types of injured tissues also fluoresce.

To obtain further evidence regarding the accuracy of the ultraviolet-light method, extensive greenhouse experiments were conducted during 1941 which were primarily designed to compare the accuracy of the ultraviolet-light method with the gram stain method for selecting "disease free" seed stocks.

Materials and Methods

From a stock of Netted Gem potatoes which had shown considerable bacterial ring rot in previous gram stain tests, 148 tubers were selected at random for ultraviolet-light examinations, 148 for gram stain tests, and 25 for a check. All uncut tubers were surface-sterilized by soaking for three minutes in a solution of mercuric chloride ($HgCl_2$), strength 1 to 1000, and the knives used in cutting the tubers were soaked for ten seconds in a solution of mercuric chloride ($HgCl_2$), strength 1 to 500. After examination, two seed pieces approximately two ounces in size (one designated as A and B) were cut from the area nearest the stem end of each tuber. Each seed piece was then planted in a six-inch clay pot containing ordinary field soil to which was added a small amount of manure and sand, and then kept in a greenhouse at a temperature of approximately 60° F.

The ultraviolet-light examinations of the tubers were made according to the method described by Iverson and Kelly (1, 2). By this examination the potatoes were classified into three groups: (1) Those which were considered to be free from bacterial ring rot, and (2) those which were considered to be infected with bacterial ring rot; and (3) those which were considered "doubtful" because of fluorescence somewhat different from that in the second group.

The gram stain tests were made according to the method outlined by Saville and Racicot (4), modified by taking the sample around the entire vascular ring.

Approximately one month after planting, examinations were made for plant emergence as noted in table 1. A few of the plants did not emerge because the seed piece decayed. In no case, however, were the

TABLE 1.—*Comparative effectiveness of the ultraviolet-light and the gram stain methods for selecting potato seed stocks free from bacterial ring rot*

	Number of Seed Pieces Planted		Number of Plants Emerged		Stems				Tubers				Per Cent of Hills Showing Brown Vascular Discoloration in Tubers
					Total Number		Per Cent Infected		Total Number		Per Cent Infected		
	A	B	A	B	A	B	A	B	A	B	A	B	
Ultraviolet-light Examination:													
Healthy	103	103	102	102	116	113	....	....	335	334	....	....	4.4
Diseased	15	15	13	13	13	13	92.31	92.31	36	30	83.33	70.00	....
Doubtful	30	30	28	30	30	33	10.00	9.09	88	74	4.55	8.11	38.0
Gram Stain Examination:													
Healthy	117	117	117	116	128	125	....	....	365	370	....	....	14.5
Diseased	31	31	29	29	30	29	93.33	96.55	75	69	66.67	73.91	....
Check—No Examination	25	25	24	25	26	26	11.54	15.38	78	75	8.97	10.67	12.0

non-sprouting seed pieces from the "healthy" groups found to contain bacterial ring rot. All of the plants were allowed to grow to maturity, but before this time most of the plants in the "diseased" groups developed ring rot symptoms. Just prior to harvesting, gram stain tests were made upon every stem from the plants in each group, but no stem infection was found in either of the "healthy" groups, as shown in table 1.

After harvesting, every tuber grown in the pots and many of the old seed pieces remaining in good condition were carefully examined by the gram stain method for the presence of bacterial ring rot. Again, none of the disease was found in the "healthy" groups resulting from either the ultraviolet-light examinations or the gram stain tests. Most of the old seed pieces from the "diseased" groups were too badly decomposed to permit further examination.

In addition to bacterial ring rot, a certain amount of brown vascular discoloration was noted in tubers from a number of hills. From the table, however, it is apparent that by the ultraviolet-light examination of the seed stock, the percentage of these other diseases was materially reduced in the "healthy" group, since all seed pieces showing disease were placed in the "doubtful" group and thereby eliminated.

Summary and Conclusions

In tests to compare the accuracy of the ultraviolet-light and the gram stain methods for selecting potato seed stocks free from bacterial ring rot, it was found: (1) That the ultraviolet-light method was just as effective as the gram stain method; (2), that the ultraviolet-light examinations were made in less than one-tenth of the time necessary for the gram stain tests; and (3), that the ultraviolet-light method had additional value in reducing the incidence of other "vascular" diseases.

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RELATION OF FIELD PLOT DESIGN TO SEED-SOURCE TESTS OF IRISH POTATOES IN THE SOUTH[1], [2]

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INTRODUCTION

The paramount concern of the southern grower of Irish potatoes for table stock is to obtain a high yield of marketable tubers. Any device that will aid in determining good certified seed stocks will tend to make production more profitable. Seed-source tests to determine the behavior of seed lots for southern plantings have been in operation for some time. The value of such tests to producers of certified seed and to certification officials in the North has already been established. Information to be secured from these tests should include (1) disease data and (2) yielding ability of the sample lots.

DISEASE DATA

Replicated plots in the form of randomized blocks would be adequate for the determination of disease data. These data should include the number of (1) weak plants, (2) virus-infected plants, (3) plants with bacterial ring rot, and (4) those with any other foliage diseases.

YIELDING ABILITY

The fundamental difficulty in seed-source tests for yield is that the control of factors affecting the yielding ability of the seed lots under investigation can never be perfect or even approximately so. Different seed lots cannot be grown simultaneously in the same space; and

[1]Cooperative investigations by the Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, and the Department of Horticultural Research of the Louisiana Agricultural Experiment Station.

[2]Presented by request at Dallas, Texas, on December 30, 1941, as part of a symposium on "Benefits Derived from Certified Seed Test Trials."

[3]Pathologist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture; headquarters at Baton Rouge, Louisiana.

when they are planted on separate plots as they necessarily have to be, inherent differences in soil fertility between these plots immediately constitute a disturbing influence. Moreover, the yield of a seed lot cannot be regarded as having a definite value. It is of significance only in relation to other yields, and in practice statistical methods are essentially concerned with the measurement of differences.

Such seed-source tests usually involve the testing of a large number of seed lots. With a large number of seed lots, arrangements in randomized blocks each including all the seed lots, will usually be effective in eliminating fertility differences because of the large space required for the replications. Latin square arrangements are impracticable because they would require too many replications, entailing too much land and expense.

A reduction in number of seed lots per test can be obtained by making separate yield tests for each variety of potatoes. For example, all of the seed lots of the Triumph variety can be tested in one experiment and all lots of the Katahdin variety in another. Such a procedure would be justified on the basis that seed-source tests are not concerned with a comparison of the yielding ability between varieties. The important point in these tests is to determine the difference in yielding ability between seed lots within varieties.

Even with the separation on the basis of varieties there would still be required the testing of a large number of sample lots of each variety. In order to further overcome the effect of soil variability on yield, Yates has developed field-plot designs which make possible the use of blocks containing only a few of the seed lots. Most of these designs may be classified as "quasi-factorial." Such designs are usually more efficient than ordinary randomized blocks. This is particularly true when the soil is very heterogeneous.

A number of different types of quasi-factorial designs have been developed, but only two will be discussed as they would seem to be of greatest practical value for seed-source tests. The designs to be discussed are known as (1) two-dimensional quasi-factorial (lattice) and (2) quasi-Latin squares (triple lattice). A complete discussion of these designs together with the analysis of the data will be found in an article by Cox, Eckhardt, and Cochran published at Iowa Agr. Exp. Sta., Res. Bull, 281, 1940.

Lattice Design

Assuming that 81 seed lots are to be tested, the first step is to assign numbers to the 81 seed lots and arrange them in the form of a square:

1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18
19	20	21	22	23	24	25	26	27
28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53	54
55	56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81

By taking the seed lots in sets of 9 each according to the rows of the above square one can make up a group containing 9 blocks of 9 seed lots each. Therefore, the first block would contain seed lots 1, 2, 3, 4, 5, 6, 7, 8, and 9. This grouping of the 81 lots is commonly referred to as the "X" group. Similarly, by taking the seed lots in sets according to the columns of the above square, another group of 9 other blocks of 9 seed lots each can be prepared. The first block of this group would consist of seed lots 1, 10, 19, 28, 37, 46, 55, 64, and 73. This second arrangement is referred to as the "Y" group. These two groups of blocks are as follows:

Blocks	*Group X*								
(a)	1	2	3	4	5	6	7	8	9
(b)	10	11	12	13	14	15	16	17	18
(c)	19	20	21	22	23	24	25	26	27
(d)	28	29	30	31	32	33	34	35	36
(e)	37	38	39	40	41	42	43	44	45
(f)	46	47	48	49	50	51	52	53	54
(g)	55	56	57	58	59	60	61	62	63
(h)	64	65	66	67	68	69	70	71	72
(i)	73	74	75	76	77	78	79	80	81

Blocks	*Group Y*								
(a)	1	10	19	28	37	46	55	64	73
(b)	2	11	20	29	38	47	56	65	74
(c)	3	12	21	30	39	48	57	66	75
(d)	4	13	22	31	40	49	58	67	76
(e)	5	14	23	32	41	50	59	68	77
(f)	6	15	24	33	42	51	60	69	78
(g)	7	16	25	34	43	52	61	70	79
(h)	8	17	26	35	44	53	62	71	80
(i)	9	18	27	36	45	54	63	72	81

It is then necessary to randomize the blocks within each replication or group and also randomize the seed lots within each block. The only restriction on the number of replications is that for this design they must be in multiples of two.

Triple Lattice Design

When another grouping, Z, of the 81 lots is added to the groups, X and Y of the lattice design we form what is known as the triple lattice.

Since the number of seed lots to be tested by this method is always a perfect square, it is possible to superimpose a Latin square arrangement on the square composed of the seed-lot numbers used in the lattice square design. Below is a Latin square for 9 letters from A to I.

A	I	H	G	F	E	D	C	B
B	A	I	H	G	F	E	D	C
C	B	A	I	H	G	F	E	D
D	C	B	A	I	H	G	F	E
E	D	C	B	A	I	H	G	F
F	E	D	C	B	A	I	H	G
G	F	E	D	C	B	A	I	H
H	G	F	E	D	C	B	A	I
I	H	G	F	E	D	C	B	A

The above Latin square when superimposed on the Group X of the seed-lot numbers of the lattice design would be as follows:

A1	I2	H3	G4	F5	E6	D7	C8	B9
B10	A11	I12	H13	G14	F15	E16	D17	C18
C19	B20	A21	I22	H23	G24	F25	E26	D27
D28	C29	B30	A31	I32	H33	G34	F35	E36
E37	D38	C39	B40	A41	I42	H43	G44	F45
F46	E47	D48	C49	B50	A51	I52	H53	G54
G55	F56	E57	D58	C59	B60	A61	I62	H63
H64	G65	F66	E67	D68	C69	B70	A71	I72
I73	H74	G75	F76	E77	D78	C79	B80	A81

The 9 blocks of Group Z are obtained from the above combination of the superimposed Latin square and the square composed of the seed-lot numbers. Thus, place the numbers corresponding to the letter A in the first of a new group of blocks, and the numbers corresponding to B in the second, and so on. When completed we have the group Z as follows:

Block	*Group Z*								
(a)	1	11	21	31	41	51	61	71	81
(b)	10	20	30	40	50	60	70	80	9
(c)	19	29	39	49	59	69	79	8	18
(d)	28	38	48	58	68	78	7	17	27
(e)	37	47	57	67	77	6	16	26	36
(f)	46	56	66	76	5	15	25	35	45
(g)	55	65	75	4	14	24	34	44	54
(h)	64	74	3	13	23	33	43	53	63
(i)	73	2	12	22	32	42	52	62	72

The triple lattice arrangement is, therefore, made up of groupings X, Y, and Z. The randomization is the same as for the lattice design. That is, the groups, the blocks in each group, and the plots in each block are arranged at random. These 3 groups comprise three replications. The number of replications for this design are in multiples of 3. Therefore the design can be arranged in 6 or 9 replications by using other random arrangements of the 3 groups.

Discussion

The designs discussed in this article have certain disadvantages, the main one of which is the fact that additional replications must be in

multiples of 2 or 3, depending on the type of design. However, for the testing of yielding ability of seed-source lots either 3 or 4 replications would be all that could be conveniently handled. The triple lattice design is suitable for 3 replications and the lattice design for 4. Although randomized block designs can be constructed for any number of varieties, the lattice designs are more restricted in this respect since the number of seed lots to be tested must be a square of a whole number. It may frequently occur that the seed lots to be tested are not sufficient in number for one of the lattice designs. This can be overcome by adding dummy seed lots to bring the total up to that required by the design.

Information has been published by LeClerg and Henderson on the relative efficiency of the lattice design as compared with a randomized-block arrangement when concerned with yields of potatoes. The data from LeClerg and Henderson are given in table 1.

TABLE 1.—*Relative efficiency of a lattice design as compared with a randomized-block arrangement in experiments containing different numbers of varieties of Irish potatoes and at 3 different locations*

Number of Varieties	Gain or Loss (Per cent) in Efficiency from Using the Lattice Design		
	England	Canada	Minnesota
100	+44.9	.....	.....
81	+31.2	+191.1	.....
64	+41.0	+232.5	.....
49	+52.0	+213.7	.....
36	— 6.3	+115.9	+38.6
25	— 7.4	— 10.2	+ 6.3
16	—10.1	— 10.4	— 8.7
9	—11.7	— 12.8	— 8.5

From the data in table 1 it appears that the lattice design was more efficient than a randomized block arrangement when the tests contained 36 or more hypothetical varieties. Therefore, it is apparent that these designs would be well suited for seed-source tests where large numbers of seed lots are to be tested. They are particularly efficient when the soil is very heterogeneous.

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EFFECT OF DIFFERENT SOURCES OF PHOSPHORUS ON THE PRODUCTION OF POTATOES ON LONG ISLAND*

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There has been some interest recently in the relative value of different sources and compositions of phosphorus for potatoes. Superphosphate of a 20 per cent or 32 per cent P_2O_5 analysis is the most popular form, but ammophos (11 per cent N : 48 per cent P_2O_5), potassium metaphosphate (60 per cent P_2O_5, 40 per cent K_2O) mono-calcium chlorophosphate (32 per cent P_2O_5), nitrophoska (15 per cent N : 30 per cent P_2O_5 : 15 per cent K_2O) and soft or colloidal phosphate (20-30 per cent P_2O_5) have received varying attention.

There are several factors which the potato grower should consider in the selection of a suitable phosphate source. First it is essential to select a phosphate which will not change the soil reaction either into a low yielding acid range, *i. e.*, below pH 5.0, or above into a scab-inducing alkaline range, *i. e.*, pH 5.5 or above; second, ease of application when mixed with nitrogen and potash carriers, particularly where band placement machinery is employed requiring accurate control and uniform flow; third, adequate availability of the phosphate to the plants throughout their growing period.

For practical purposes a valid comparison of the various sources can be made on the basis of their effect upon marketable yield of the crop in question. Causes of gross differences can then be examined and

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reasons for the observed differences in yield allocated to some specific property of the phosphatic source responsible for the difference.

Materials and Methods

Two experiments were set up in 1939 which was a very dry season on Long Island. One was located at the Research Farm, and was part of a larger experiment, and the other was planted on the Dart Farm at Southold. The Research Farm experiment (1) involved a comparison of superphosphate and soft phosphate, wherein each source was distributed in three ways:

1. 50 per cent of the phosphate source applied in each band on either side and slightly below the seed piece, in combination with the nitrogen and potash components of the complete fertilizer.
2. 25 per cent of the phosphate source in each band with the nitrogen and potash, and the remaining 50 per cent in actual contact with the seed piece.
3. 100 per cent of the phosphate source in contact with the seed piece, and none in combination with the nitrogen and potash which remained in side bands.

The fertilizer analysis employed is given in table 1.

The Dart Farm experiment (2) comprised a single factor study of phosphate source, wherein four sources,—superphosphate, ammophos, nitrophoska and soft phosphate were employed at a constant rate of N, P_2O_5, and K_2O. The actual composition of the fertilizers employed are given in table 2.

Both of the 1939 experiments were conducted with the Green Mountain variety. In 1940, a favorable year, two additional experiments were conducted, both at the Research Farm. One (3) was an exact replication of experiment (1) repeated with the Cobbler variety, the other (4) was of similar type to (2) except potassium metaphosphate, and mono-calcium chlorophosphate were substituted for ammophos and nitrophoska; and the Cobbler variety was employed. The exact fertilizers employed are presented in tables 3 and 4 respectively for the 1940 experiments.

The soil type in all four experiments was Sassafras silt loam, with a reaction of pH 5.3-5.5 at the start of the experiments. This soil

TABLE 1.—*Yields of Green Mountain potatoes obtained from different sources of phosphorus in conjunction with various placements.* (*Experiment 1—1939*)

Source of Phosphate	P_2O_5 Per Cent	Phosphate Placement			Yields in Bushels per Acre				Source Means	
		Left Band	Contact with Tuber	Right Band	U. S. No. 1	Total	Placement Means		U. S. No. 1	Total
		%	%	Per Cent						
Superphosphate	20	50	0	50	93	128			87	114
		25	50	25	78	100				
		0	100	0	90	113	U. S. No. 1	Total		
Soft phosphate	20	50	0	50	67	94	80	111	82	105
		25	50	25	100	122	89	111		
		0	100	0	78	99	84	106		

NOTE: The general fertilizer applied was 2,000 lbs. of 5-10-5 analysis per acre. The nitrogen was provided by ⅔ nitrate of soda (16 per cent N), ⅓ ammonium sulphate (20 per cent N), the potash was provided by potassium chloride (50 per cent K_2O), and the phosphate as given above. Ground Lime and Cocoa shells were used as filler, the Lime being adjusted to provide a neutral residual affect.

TABLE 2.—*Yields of Green Mountain potatoes with various sources of phosphorus. (Experiment 2—1939)*

Treatment Mixtures	Source of Phosphorus	Associated Fertilizers	Analysis			Weight Applied Lbs. / A.	Wt. Nutrient Lbs. per Acre			Yields	
			N	P_2O_5	K_2O		N	P_2O_5	K_2O	U. S. # 1	Total
1	Superphos.	Ammon. Sulph.	0	20	0	1000	—	200	—		
		Pot. Chloride	20	0	0	500	100	—	—		
		Filler—Sand	0	0	60	167	—	—	100		
			—	—	—	333	—	—	—		
				Total		2000	100 (5%)	200 (10%)	100 (5%)	215	237
2	Soft Phosphate	Ammon. Sulph.	0	20	0	1000	—	200	—		
		Pot. Chloride	20	0	0	500	100	—	—		
		Filler—Sand	0	0	60	167	—	—	100		
			—	—	—	333	—	—	—		
				Total		2000	100 (5%)	200 (10%)	100 (5%)	263	303
3	Ammophos.	Ammon. Sulph.	11	48	0	417	46	200	—		
		Pot. Chloride	20	0	0	270	54	—	—		
		Filler—Sand	0	0	60	167	—	—	100		
			—	—	—	1146	—	—	—		
				Total		2000	100 (5%)	200 (10%)	100 (5%)	190	217
4	Nitrophoska	Filler—Sand	15	30	15	667	100	200	100		
			—	—	—	1333	—	—	—		
				Total		2000	100 (5%)	200 (10%)	100 (5%)	255	288

TABLE 3.—*Yields of Cobbler potatoes obtained from different sources of phosphorus in conjunction with various placements. (Experiment 3—1940)*

Source of Phosphate	P_2O_5 Per cent	Phosphate Placement			Yields in Bushels per Acre					
		Left Band	Contact with Tuber	Right Band	U. S. #1	Total	Placement Means		Source Means	
									U. S. #1	Total
		%	%	%						
		50	0	50	319	354				
Superphosphate	20	25	50	25	329	364			300	333
		0	100	0	251	283	U. S. #1	Total		
		50	0	50	248	295	284	325		
Soft Phosphate	20	25	50	25	202	251	266	308	237	286
		0	100	0	260	312	256	298		

NOTE: The general fertilizer applied was 2,000 lbs. of 5-10-5 analysis per acre. The nitrogen was provided as 2/5 sodium nitrate (16 per cent N) and 3/5 Uramon (42 per cent N), the potash was provided by potassium chloride (60 per cent K_2O), and the phosphate as given above. Ground lime and cocoa shells were used as filler, the lime being adjusted to provide a neutral residual affect.

TABLE 4.—*Yields of Cobbler potatoes produced by various sources of phosphorus. (Experiment 4—1940).*

Treatment Mixtures	Source of Phosphorus	Associated Fertilizers	Analysis N Per cent	Analysis P_2O_5 Per cent	Analysis K_2O Per cent	Weight Applied Lbs. / A.	Wt. Nutrients Applied Lbs. per Acre N	P_2O_5	K_2O	Yields as Bus. per Acre U. S. #1	Total
1	Superphos.	Sod. Nitrate	—	20	—	1000	—	200	—	237	275
		Pot. Chloride	16	—	0	625	100	—	—		
		Filler—Sand	—	—	60	167	—	—	100		
			—	—	—	208	—	—	—		
				Totals		2000	100	200	100		
2	Soft Phos.	Sod. Nitrate	—	20	—	1000	—	200	—	226	263
		Pot. Chloride	16	—	—	625	100	—	—		
		Filler—Sand	—	—	60	167	—	—	100		
			—	—	—	208	—	—	—		
				Totals		2000	100	200	100		
3	Pot. meta Phosphate	Sod. Nitrate	—	60	40	333	—	200	133	212	259
		Filler—Sand	16	—	—	625	100	—	—		
			—	—	—	1042					
				Totals		2000	100	200	133		
4	Mono - cal chloro-phos.	Sod. Nitrate	—	32	—	625	—	200	—	250	279
		Pot. Chloride	16	—	—	625	100	—	—		
		Filler—Sand	—	—	60	167	—	—	100		
			—	—	—	583					
				Totals		2000	100	200	100		

has been shown repeatedly to require a dressing of at least 100 lbs. of P_2O_5 per crop to produce adequate yields of potatoes.

The experiments were designed in randomized blocks, there being three such blocks in 1939 and four in 1940.

Experimental Results

The results of experiment 1 are presented in table 1, and the essential statistical data in table 1a.

Table 1a.—*Statistical analysis of experiment 1.*

Source of Variation	Degrees Freedom	Variance
Treatment (T)		7.65
(Superphos v Soft Phos. (S)	1	4.40)
(2x50: 0: 50 placement v 25: 50: 25 + 0: 100: 0 (P′)	1	0.32)
(25: 50: 25 placement v 0: 100: 0 (P″)	1	0.84)
(Interaction S X P″	1	19.29)
(Interaction S X P′	1	13.25)
Block (B)	2	44.28
Error (T X B)	10	10.59
Grade (U. S. No. 1 v U. S. No. 2) (G)	1	406.56**
Interactions G X S	1	0.21
(T X G) G X P′	1	6.55
G X P″	1	0.64
G X S X P′	1	3.52
G X S X P″	1	5.16
Error (T X B X G — T X B)	12	6.21

**Significant at 1 per cent pt.

From table 1a, it can be concluded that with the exception of the difference between grades, no other factor in the experiment produced an effect of any significance. Thus the two sources of phosphorus were equally efficacious, as were the three methods of applying phosphate, and either source of phosphorus produced the same results regardless of how it was applied. Both sources also had the same effect upon grade of tubers regardless of how they were applied. Therefore this experiment clearly indicates that under the conditions experienced, the two sources of phosphorus were of equal value.

The results of experiment 2 are presented in table 2, with the attendant statistical data presented in table 2a.

From these data it may be concluded that in this experiment superphosphate was significantly inferior to the soft phosphate as a phos-

TABLE 2a—*Statistical analysis of experiment 2.*

Source	Degrees Freedom	Variance
Treatment (T)	3	31.49**
(Superphos + Soft Phos. v Ammophos + Nitrophoska	1	5.73)
(Superphos v Soft Phos.	1	41.03**)
(Ammophos v Nitrophoska	1	47.71**)
Block (B)	2	21.59
Error (T X B)	6	2.77
Grade (G)	1	1524.98***
T X G	3	7.71
Error (T X B X G — T X B)	8	4.52

**Significant at 1 per cent pt.
*** Significant at 0.1 per cent pt.

phorus source; and ammophos was significantly inferior to nitrophoska as a source of combined phosphorus. The comparison of phosphate as a separate entity and in chemical combination with other nutrients—nitrogen and potash—showed an insignificant difference. Therefore, the relative value of the four sources assumed a descending order of soft phosphate, nitrophoska, superphosphate and ammophos. This order was true regardless of grade, the grade distribution being the same for all sources.

The results of experiment 3 are presented in table 3. From these data it is apparent that in 1940, with the Cobbler variety, superphosphate was significantly superior to soft phosphate regardless of grading. The distribution of the phosphate sources, however, showed an interesting inverse effect. Thus, as superphosphate was dispersed from one band in contact with the tuber, to two at the side, to one in contact and two at the side its efficacy progressively increased, whereas soft phosphate showed the reverse, the best effect arising from a single band in contact, and increased dispersion reduced yield.

The optimum placement for superphosphate was, nevertheless, significantly better than that for the soft phosphate.

Tables 4 and 4a contain the data resulting from experiment 4.

From these data it may be concluded that all four sources were equally effective in the production of tubers regardless of grade.

DISCUSSION

Fom these four experiments it appears that five of the six sources studied are equally efficient in providing adequate phosphoric acid in

TABLE 4a.—*Statistical analysis of experiment 4.*

Source of Variation	Degrees Freedom	Variance
Total (T X B)	15	
Treatment (T)	3	14.83
Block (B)	3	6.19
Error	9	12.83
Total (T X B X G) — (T X B)	16	
Grade (G)	1	3883.66***
Interaction (T X G)	3	13.55
Error	12	7.27

*** Significant @ 0.1 per cent pt.

the production of potatoes on Long Island. These five are superphosphate, nitrophoska, soft phosphate, potassium metaphosphate and monocalcium chlorophosphate. Ammophos, presumably because of its active residual acid affect is apparently not so suitable on low reaction potato soils. In the four experiments, in two cases superphosphate and soft phosphate gave the same effect; in one the superphosphate was superior, and in the other the soft phosphate produced the higher yield. On the average therefore, they are essentially similar, when applied to these soils at the rate of 1000 lbs. per acre. The superphosphate had a guaranteed P_2O_5 content of 20 per cent ammonium citrate soluble, whereas the soft phosphate had a total P_2O_5 content varying from 20 to 28 per cent, of which about one-half has been found to be ammonium citrate soluble. On this basis one would expect the soft phosphate to be about 50 per cent as effective as superphosphate. However, because of its finely divided texture the tricalcium phosphate, of which it is chiefly composed may be more readily soluble in the soil solution, particularly of acid soils.

Connor and Adams (1926) have shown that availability of rock phosphate is definitely increased by grinding beyond 100 mesh. Bartholomew (1937) has shown that such ground rock phosphate is more available in soils of lower reaction. However it has also been repeatedly shown that reversion of superphosphate to tricalcium phosphate is less rapid on a soil of acid reaction than on a calcareous soil—Heck (1934), Hibbard (1935).

Probably the reason for the similar results obtained between soft phosphate and superphosphate in these experiments, where each source has been computed as 20 per cent P_2O_5, lies in the fact that 200 lbs. of phosphoric acid per acre is actually an excess application, on these soils. No experimental data has indicated that more than 120 lbs. P_2O_5 per

acre is required for a single crop of potatoes. Nevertheless, local growers invariably apply 200 lbs. phosphoric acid and in some cases more, per acre, for potatoes. It is probably a sound conclusion to assume that soft phosphate has about two-thirds to three-quarters the value of superphosphate on these soils, and could therefore compete on such a price basis. Certainly there is no evidence at hand to support some of the exorbitant claims that have been made for soft phosphate, largely based upon its colloidal condition. It doubtless contains certain minor elements, which may prove of value under specific conditions, but at present it can be regarded primarily as a source of phosphorous and, to some extent, of calcium.

Potassium metaphosphate and monocalcium chlorophosphate appear to have equal value to superphosphate, the former having the added advantage of being an adequate source of potash. Both these materials require further study and testing, but it seems probable they will develop more rapidly as double strength fertilizers gain in popularity.

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THREE YEARS' COMPARISONS OF DUSTS AND BORDEAUX SPRAY FOR POTATO PRODUCTION IN CENTRAL JERSEY

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Mixtures of copper sulfate and lime applied either as bordeaux mixture or copper-lime dust are standard materials in New Jersey for the control of flea beetles, leafhoppers, and foliage diseases affecting Irish potatoes. These materials possess the advantage of being effec-

Mr. Andrew Kutch, Mr. Oscar Danser, and Mr. Clendon Danser (Cranbury, N. J.) were the cooperators on whose farms these tests were conducted.

tive, as well as being economical and easily applied. Several copper fungicides, other than bordeaux mixture, have been tested, with and without lime, and found to be inferior to bordeaux mixture under New Jersey conditions.

During the past few years a group of plant extracts (alkaloids) possessing insecticidal properties have come into general favor for certain uses. This group consists of such materials as pyrethrum and rotenone. Experiments conducted here (1), and elsewhere (2, 3, 4) have shown that rotenone is effective in reducing flea beetle populations whereas pyrethrum is more toxic to leafhoppers.

In the experiments discussed in this paper, bordeaux mixture and copper-lime dust are compared with pyrethrum and rotenone, used alone or jointly, as foliage protectants in Central New Jersey.

Experimental

For a 3-year period, beginning in 1938, experiments were conducted in which (1) bordeaux mixture (10-10-100); (2) copper-lime dust (30-70); (3) rotenone-sulfur dust (15 per cent cube [5 per cent rotenone], 35 per cent sulfur, and 35 per cent bancroft clay;) (4) pyrethrum-sulfur dust (15 per cent pyrethrum, 35 per cent sulfur, and 50 per cent bancroft clay;) and (5) pyrethrum-rotenone-sulfur dust (15 per cent pyrethrum, 15 per cent cube [5 per cent rotenone], 35 per cent sulfur, 35 per cent bancroft clay) were compared as foliage protectants for the Irish Cobbler variety of potatoes. All the materials were applied to the foliage during the day when the foliage was dry. The bordeaux mixture was applied with a 10-row Friend tractor trailer sprayer delivering 100 to 125 gallons per acre at 350 pounds pressure. The dust applications were made with a 6-row Messinger tractor trailer duster operated from the power take off. The materials used were applied at intervals which varied from 7 to 10 days, beginning after an application of copper, calcium arsenate and lime were applied to the entire test area for the control of Colorado potato beetles. In 1938 all test plots received six applications, and in 1939 and 1940 all plots received five applications exclusive of the dust applied for the control of the potato beetle. In these tests the dusted and sprayed treatments were repeated three times with the plots randomized within the blocks. Yield records were taken in 1938 and 1940, from two 1/60 of an acre sections from each dusted plot, making a total of six such sections for each treatment. In 1939 records were taken from three sections in each plot making a total of nine sections for each treatment. These harvested

sections were two rows wide and consisted of the two center rows. For the bordeaux-sprayed plots yield records were taken in 1938 and 1940 from four 1/60 of an acre sections from each plot, making a total of twelve such sections for this treatment. In 1939 yield records were taken from six sections in each plot making a total of eighteen sections for the treatment. These harvested sections were likewise two rows wide, one section consisting of the two center rows and the other section consisting of the two adjoining, unstraddled rows. In calculating the weighted average yield for the treatment the middle or straddled section was considered as representing two rows while the adjoining two rows were considered as representing the remaining eight rows of the ten-row treatment. Although this method of calculating yields favors the spray treatment somewhat, the amount is not great since the average difference in yields between the rows influenced by sprayer wheels and those that were not so influenced was only 3 per cent.

Results in 1938

The months of June and July were unusually wet, with a total of 19.56 inches of rainfall in the vicinity of the test. This is 10.88 inches above the average for this period. The resulting high humidities coupled with favorable air temperatures made possible an outbreak of late blight. Data recorded from leaf counts on the 9th of July showed that the sulfur, rotenone, pyrethrum combinations provided poor control of late blight (see table 1), whereas copper-lime dust was intermediate in this respect. From the data it is evident that bordeaux mixture was much superior, as a fungicide, when compared with the other materials tested.

Of the insect pests affecting the potatoes in the experimental plots, flea beetles were perhaps the most destructive, since they were present in large numbers throughout July. Leafhoppers were not present in large numbers until very shortly before the death of the plants. Because of late blight injury in most of the dusted blocks, an accurate count of tip-burned leaves was rendered difficult. Aphids were not numerous enough to cause any special concern.

Of the materials tested, bordeaux mixture provided more protection against flea beetle injury to foliage than did any of the other treatments included in the test (see table 1), whereas pyrethrum-sulfur provided the least protection. The other materials were about equally effective, as judged by the number of holes in the leaves which were produced by flea beetles during feeding.

The growing season was terminated rather abruptly by a combina-

tion of heavy rains, late blight and an extremely heavy outbreak of flea beetles. Most of the flea beetles migrated into the experimental plots from nearby fields. Under these adverse conditions, however, the plants in the copper-treated blocks remained alive from a few days to a week longer than did those in the sulfur-alkaloid dusted treatments. The bordeaux-sprayed plots produced the highest yields as shown in table 1, whereas the pyrethrum-sulfur dusted plots produced the poorest yields of any of the treatments tested. In this test the bordeaux mixture spray excelled copper-lime dust from the standpoints of disease and insect control and also in the yields produced.

TABLE 1.—*Results from spraying and dusting test*—1938.

Materials	Foliage Counts—July 9		Ave. Yield in Bu. Per Acre
	Per Cent Leaflets Showing Late Blight	No. of Flea Beetle Punctures Per Leaflet	
1. Bordeaux Mixture (10-10-100)	9	27.5	469.0
2. Copper-Lime Dust (30-70)	19	43.5	446.3
3. Rotenone-Sulfur	37	38.6	446.3
4. Pyrethrum-Sulfur	45	59.7	423.1
5. Pyrethrum-Rotenone-Sulfur	46	41.1	447.8

Difference in yield necessary for significance (odds 19-1) 22.9 bu.
Yield data analyzed by Fisher's method for the analysis of variance.

After harvest, two, one hundred-pound sacks from each of the following treatments, bordeaux mixture, copper-lime dust, and pyrethrum-rotenone-sulfur dust, were placed in common storage. The potatoes at the time of storage were free from visible decay. After a four-week period these potatoes were examined for late blight rots and the following percentages of potatoes were found to have visible decayed areas:

Bordeaux Mixture (10-10-100)	0.05 per cent of potatoes decayed
Copper-Lime Dust (30-70)	1.5 per cent of potatoes decayed
Pyrethrum-Rotenone-Sulfur Dust	20.0 per cent of potatoes decayed

RESULTS IN 1939

The growing season of 1939 was a dry one with the total rainfall being well below average for all months concerned. Under such condi-

tions foliage diseases were not a problem; however, aphids were extremely numerous and constituted the chief limiting factor in potato production. Although flea-beetles were numerous, they were only of secondary importance when compared with the high aphid populations.

From the flea beetle puncture counts that were made on the 3d of July (table 2), it was found that bordeaux mixture provided more protection against this insect than did any of the other materials tested.

On the 20th of July all plants, regardless of treatment, showed considerable dead foliage. However, the plants in the plots treated with materials containing rotenone looked better throughout the latter part of the growing season than did the plants in the rest of the experimental area. As the season progressed the plots receiving bordeaux mixture, and to a much less extent, copper-lime dust, showed excessive aphid injury which was largely responsible for the low yield of the bordeaux treatment. This may have been caused by aphid attracting properties possessed by white spray residues.

TABLE 2.—*Results from spraying and dusting test—1939*

Materials	Ave. No. of Flea Beetle Punctures Per Leaflet July 3	Ave. Yield in Bu. Per Acre
1. Bordeaux Mixture (10-10-100)	28.7	171.3
2. Copper-Lime Dust (30-70)	38.8	191.1
3. Rotenone-Sulfur	39.9	191.0
4. Pyrethrum-Sulfur	43.4	192.6
5. Rotenone-Pyrethrum-Sulfur	35.0	198.9

Difference in yield necessary for significance (odds 19-1) 12.4 bu.
Difference in yield necessary for significance (odds 99-1) 16.7 bu.

RESULTS IN 1940

During the three-year period of this test the driest June and July ever experienced occurred in 1940. During these two months 3.63 inches of rain fell in the vicinity of the test, only 41 per cent of the average for the period. In this test foliage diseases were not a problem. However, flea beetles were plentiful during the latter part of the growing season.

From the data recorded in table 3 it appears that of all the materials used in the test, pyrethrum-sulfur was the least effective as a

flea beetle repellent, whereas bordeaux was again one of the most efficient materials used in repelling this insect. Another point of interest is, that the dusted plots yielded equally as well as the wet-sprayed plots. This was true despite the fact that the bordeaux-sprayed plants remained green for approximately a week longer than did the plants in the dusted plots.

TABLE 3.—*Results from spraying and dusting test*—1940.

Materials	Ave. No. of Flea Beetle Punctures Per Leaflet July 19	Ave. Yield in Bu. Per Acre
1. Bordeaux Mixture (10-10-100)	23.2	309.0
2. Copper-Lime Dust (30-70)	31.0	306.8
3. Rotenone-Sulfur	25.7	310.2
4. Pyrethrum-Sulfur	66.6	307.1
5. Rotenone-Pyrethrum-Sulfur	29.8	305.8

GENERAL CONCLUSIONS

During the three-year period that this test was in progress, a variety of growing seasons was experienced. Perhaps the chief factors limiting yields during this period were: late blight and flea beetles during 1938; insufficient moisture and aphids in 1939; and insufficient moisture during 1940. From the results of these three years of experimentation it is clear that no one foliage protectant is best under all conditions. Of the materials tested Bordeaux mixture gave the best protection against late blight. This material also ranks high as a flea beetle repellent, although not shown here, as a leafhopper repellent. During periods when aphids are serious, however, bordeaux mixture seems to leave an undesirable spray residue when used as a foliage protectant. The yield records for 1940 are very interesting. During that season insects were kept in check by bordeaux as well as any other treatment and the bordeaux-sprayed plants remained green longer than did those in all other treated plots. Despite these facts the bordeaux-sprayed plots yielded no more than the other treatments. It is possible that some deleterious effect of bordeaux mixture, under the conditions of insufficient moisture as it existed in this test, counter-balanced the benefits of good insect control and the prolonged growing period.

An additional point of interest is a comparison of the yield performance between the Bordeaux mixture-sprayed and the copper-lime

dusted plots. From this comparison it may be seen that in the 1938 test, where flea beetles became exceptionally severe and late blight was a problem, the plots sprayed with bordeaux mixture outyielded the copper-lime dusted plots. This was probably caused by the failure of the dust to check flea beetle injury and to prevent the development of late blight as effectively as did bordeaux mixture. However, in 1939 the dusted plots outyielded the sprayed plots when aphids were severe. In 1940, when neither late blight nor aphids were unusually severe, the dusted and sprayed plots were equally good.

From late blight control and yield records secured during the late blight year (1938), it is apparent that the sulfur-alkaloid combinations are undesirable for use where late blight is present. When aphids were present in large numbers (1939), the plants in the rotenone dusted plots looked better than the plants which received the other materials. This improvement in vine appearance, however, was not reflected in the yields when the rotenone dusted plots are compared with the yields from the other dusted treatments. The alkaloid-dusted plots produced equally high yields when compared with the copper-treated areas in the 1940 experiment. The results of these three years tests suggest, however, that the general use of pyrethrum-sulfur or rotenone-sulfur combinations on Irish Cobbler potatoes might be limited by the failure of these combinations to prevent late blight and by their higher costs.

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FLOWER BUD FORMATION IN THE POTATO PLANT AS INFLUENCED BY VARIETY, SIZE OF SEED PIECE, AND LIGHT

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Earlier work (1, 2, 4, 5) has shown that long photoperiods are favorable for flower and seed-ball production in the potato. However, long photoperiods are not essential for the formation of flower primordia in this plant for Jones and Borthwick (3) found that they could be initiated when the plants were grown in total darkness. In a study of the effect of photoperiod, temperature, and seed-piece size on the initiation of flower primordia they report that the first inflorescence was differentiated at approximately the same node under all treatments studied, although the small size of the seed piece, high temperature, and short photoperiod had a tendency to increase the node number to the first inflorescence. No counts were made of the total number of flower primordia initiated under the various treatments.

The present study was conducted to determine the effect of varietal differences, length of photoperiod, and source of supplementary light (Mazda vs. fluorescent) on the number of buds produced in the first inflorescence of the potato plant.

Materials and Methods

Two experiments were carried out. In one of these, 27 varieties were grown in the same environment; in the other, plants of three varieties were grown from seed pieces of three different sizes with four different light treatments.

The seed potatoes used in both experiments were grown at Presque Isle, Me., in 1940, shipped to the U. S. Horticultural Station, Beltsville, Md., in October, and held in common storage until the time of planting.

In the first experiment 12 plants of each of 27 varieties were grown in randomized blocks. Seed pieces were cut to weigh approximately 25 grams and planted in flats on December 13, 1940. On December 17 the sprouted seed pieces were planted in the greenhouse bench in rows

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8 inches apart, and spaced 8 inches in the row. All plants were grown without any supplementary light.

In the second experiment seed pieces of the Chippewa, Earlaine, and Sebago varieties were cut to three sizes (5, 25, and 45 grams) and planted in flats on the 2d of December. Sprouted seed pieces were transplanted to 4-inch pots on the 11th. Six hundred forty-eight plants were grown, 216 of each variety. All plants were pruned to single stems.

Four series of environmental conditions were provided: total darkness, natural photoperiod, natural photoperiod supplemented with Mazda, and natural photoperiod supplemented with fluorescent light. The plants of each treatment were grown in duplicate. All plants were subjected to their appropriate light treatment as soon as the sprouts emerged through the surface of the soil. The greenhouse benches were covered with black cloth placed over a light wooden framework to provide dark chambers. The plants grown in total darkness remained covered during the entire experiment. A Weston light meter registered less than 1-foot-candle when placed in this compartment. The remaining plots were covered at 4:30 p. m. Both Mazda and fluorescent lights were turned on daily at 4:30 p. m. and turned off at 2:00 a. m. One-hundred-watt Mazda bulbs with 12-inch reflectors were used. The fluorescent light tubes were mounted on a wooden frame painted with a white reflecting surface so that 10 40-watt daylight tubes, each 4 feet long, covered 12 square feet of bench space. These wooden frames were placed in position at 4:30 p. m. every afternoon and taken down every morning to avoid shading during the day. The intensity of the artificial light was approximately 20 to 30 foot-candles for the Mazda and 500 to 600 foot-candles for the fluorescent light when measured at the tip of the plants by a Weston light meter.

The temperature was maintained at approximately 65° to 75° F. during the day and 50° to 55° at night.

One-third of the plants were collected on the 2d of January; another third on the 7th, and the remainder, on the 14th. By this time differentiation of the first inflorescence was practically completed. The plants were examined under a dissecting microscope to determine the stage of development of the young inflorescence (Figure 1). In the ontogeny of the individual flower the primordium first appears as a rounded growing point of meristematic tissue. The calyx develops as a ring at the base. As growth of this ridge continues five sepals develop, and finally they enclose the young bud. It is possible to find, in a single inflorescence, flowers varying in size and stage of development from those

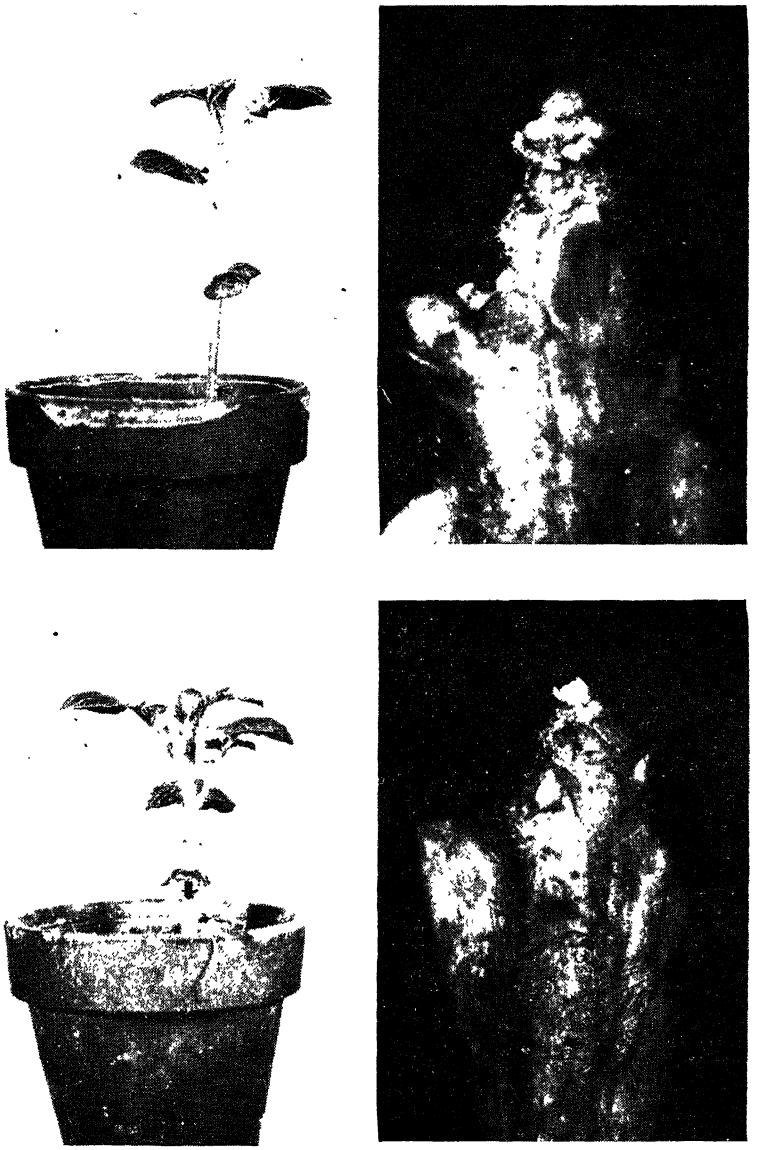

FIGURE 1.—Upper row, Triumph potato plant in which the inflorescence is at a very early stage of development. Right, photomicrograph of the apex of this same plant with leaves removed. Young flower buds are just beginning to differentiate. Lower row, Triumph potato plant in which the inflorescence is at a slightly later stage of development. Right, photomicrograph of the apex of this same plant, with leaves removed. Several young flower buds in several stages of differentiation can be distinguished.

fully open down to small, undifferentiated primordia. In this study all buds that had begun differentiation of the calyx are included in the counts. A young bud may be abscissed at an early stage leaving at the point of abscission a scar which can be readily distinguished under the dissecting microscope. These abscissed buds are also included in the bud counts.

Experimental Results

Varieties of potatoes were found to differ in the number of buds that they produced in the first inflorescence when grown in the greenhouse at Beltsville with the natural photoperiod during the winter months. The mean number of buds per plant ranged from 22.0 for British Queen and Spaulding Rose to 13.9 for Pearl. These extreme differences, as shown in table 1, proved highly significant, as they gave an F value exceeding the 1-per cent point.

Table 1.—*Mean number of buds per plant in the first inflorescence of 27 varieties of potatoes.*

Variety	Number of Buds per Plant	Variety	Number of Buds per Plant
British Queen	22.0	Wisconsin Pride	17.4
Spaulding Rose	22.0	Charles Downing	17.3
Sebec	21.3	Pontiac	17.3
Early Michigan	20.2	Golden	16.9
Early Rose	20.2	Norkota	16.9
Garnet Chili	20.2	Warba	16.8
Triumph	19.8	Houma	16.4
Mesaba	19.7	Katahdin	16.2
Quick Lunch	18.7	Brown Beauty	15.9
Red Warba	18.2	White Rose	15.4
President	18.1	Sequoia	15.1
Columbia Russet	17.8	Blue Victor	14.3
Harmony Beauty	17.7	Pearl	13.9
Green Mountain	17.5		

Difference required between means for significance at 5-per cent level=2.3 buds.
Difference required between means for significance at 1-per cent level=3.1 buds.

In the second experiment the mean number of buds produced in the first inflorescence of the potato was influenced by variety, light treatment, and size of seed piece. The varietal differences, disregarding differences resulting from light treatment and seed-piece size, are shown in table 2. In this experiment, as in the previous one, there are

TABLE 2.—*Mean number of buds per plant in the first inflorescence of three varieties of potatoes.*

Variety	Mean Number of Buds per Plant		
	January 2	January 7	January 14
Chippewa	4.7	9.3	11.9
Earlaine	9.8	13.2	15.9
Sebago	10.7	15.0	21.2
Difference required between means for significance at 5-per cent level	1.2	1.4	1.6
At 1-per cent level	1.6	1.9	2.1

differences between varieties in the mean number of buds produced. For each harvest date, Chippewa produced fewer buds than either Earlaine or Sebago, this difference being highly significant in every case. Earlaine produced fewer buds than Sebago. For the first collection this difference is too small to be regarded as significant; for the second it is significant to the 5-per cent point; and for the third it is significant to the 1-per cent point.

There is a highly significant difference for all three dates in number of buds that developed on plants from the 5- as compared with those from the 25- or the 45-gram seed pieces, the 5-gram seed piece producing fewer buds as shown in table 3. The difference between the 25- and 45-gram sizes is below the 5-per cent level of significance for the first and third collections, although exceeding the 1-per cent level for the second.

Plants grown in total darkness produced fewer buds than those that received light. As shown in table 4 this difference far exceeds the 1-per cent level of significance for all three collections. The difference in number of buds between the plants grown with the natural photoperiod and those grown with the natural photoperiod lengthened by the use of Mazda light until 2:00 a. m. in every case is too small to be considered significant. For the first and third collections plants grown with the natural photoperiod lengthened by the use of fluorescent light until 2:00 a.m. produced more buds than any of the other treatments, this increase being statistically significant. For the second collection, however, no significant difference in number of buds was obtained between the natural photoperiod, the natural photoperiod lengthened by Mazda, and the natural photoperiod lengthened by fluorescent light.

TABLE 3.—*Mean number of buds per plant in the first inflorescence from seed pieces of different sizes.*

Size of Seed Piece	Mean Number of Buds per Plant		
	January 2	January 7	January 14
Grams			
5	5.3	8.0	10.3
25	9.9	13.7	19.2
45	9.9	15.7	19.5
Difference required between means for significance at:			
5-per cent level	1.2	1.4	1.6
1 per cent level	1.6	1.9	2.1

The greatest difference in every case is that between the plants grown in total darkness compared with those receiving the other treatments.

Interactions between variety, seed-piece size, and light treatment were below the 5-per cent level of significance with the exception in certain cases of variety x size of seed piece and variety x light treatment. The interaction between variety and size of seed piece was significant to the 5-per cent level for the first and third harvest dates

TABLE 4.—*Mean number of buds per plant in the first inflorescence from potato plants grown in total darkness, the natural photoperiod, and the natural photoperiod supplemented with Mazda and with fluorescent light.*

Treatment	Mean Number of Buds per Plant		
	January 2	January 7	January 14
Darkness	1.9	2.6	4.1
Natural photoperiod	9.9	15.2	18.0
Natural photoperiod—+Mazda to 2:00 a. m.	10.0	16.4	18.8
Natural photoperiod + fluorescent to 2:00 a. m.	11.7	15.7	24.5
Difference required between means for significance:			
at 5-per cent level	1.2	2.7	2.4
at 1-per cent level	1.6	3.7	3.1

but below the 5-per cent level for the second. Variety x light treatment was highly significant for the second harvest but below the 5-per cent level for the first and third.

Discussion

It is well known that varieties of the potato differ in the number of mature flowers they produce, and that flowering is markedly influenced by environmental factors. The experimental results reported in this paper show that the difference in flower production between varieties does not result solely from differences in the amount of bud abscission but that varieties also differ in the number of flower primordia differentiated.

Results from the three collections were similar for the different treatments except that the second harvest differed slightly from the first and third. In this second collection the difference between the 25- and 45-gram seed pieces was highly significant. The difference between the fluorescent light compared with the natural photoperiod and the Mazda light treatments was below the 5-per cent level of significance. The interaction between variety and seed-piece size was below the 5-per cent level, and that between variety and light treatment was highly significant. For the other variables, however, the three collections gave similar results.

The cause of these differences cannot be determined with any certainty but is probably associated, at least in part, with the variation in natural light intensity during the period when the buds were being collected. Werner (6) has shown that light intensity is an important factor in flower and seed ball production. Preceding the first collection there were a number of dull, cloudy days; between the first and second collections there were several bright, sunny days; whereas between the second and third the weather was, on the whole, rather dull and cloudy.

The 5-gram seed pieces produced plants with a much reduced number of buds. The difference between the 25- and 45-gram sizes was relatively small and below the 5-per cent level of significance, except in the second collection when it exceeded the 1-per cent level. It would appear that under the environmental conditions existing during this experiment that the very small 5-gram seed pieces were at a considerable disadvantage, but that little, if any, increase in bud formation resulted from the use of a seed piece larger than 25 grams.

Buds were initiated by plants grown in continuous darkness. This

agrees with the results reported by Jones and Borthwick (3). The number of buds produced, however, was much less than for those plants that received light.

The differences between the other three light treatments were relatively small, although for the first and third harvests the natural photoperiod extended by fluorescent light gave an increase significant to the 1-per cent level. The greater intensity of the fluorescent light probably accounts for this, but the difference in quality between the flourescent and Mazda light may also be partly responsible. It would seem that during the dull, cloudy weather preceding the first and third collections the added intensity of the fluorescent lights produced some increase in bud initiation but that this effect was negligible in the sunny weather preceding the second collection.

The natural photoperiod and the natural photoperiod lengthened by Mazda light gave differences below the 5-per cent level in all cases so it may be concluded that lengthening the photoperiod with Mazda light of low intensity had no effect on the number of buds differentiated. The longer photoperiod favors the production of mature flowers, but this is because the abscission of young buds is reduced. Also it seems that a long photoperiod combined with a high light intensity may increase somewhat the number of buds formed. Their favorable effect on flower production, however, results chiefly from a reduction in the amount of bud abscission.

Summary

The number of young buds that develop in the first inflorescence of the potato is influenced by variety, size of seed piece, and light treatment. Fewer buds were initiated in plants from 5-gram seed pieces than from 25- and 45-gram pieces, and from plants grown in total darkness than in plants exposed to natural daylight.

No increase in the number of buds differentiated was obtained by lengthening the natural photoperiod with Mazda light of low intensity. An increase significant to the 1-per cent level was obtained from two collections made in dull, cloudy weather by lengthening the natural photoperiod with fluorescent light of higher intensity.

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SURVEY OF POTATO DISEASES IN PEAT SOILS IN CALIFORNIA

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The wilting of potato vines in commercial fields is one of the first indications that the plant is not normal. Although it is of common occurrence it is important to ascertain the real cause of it. The correct diagnosis very often leads to measures that will reduce or eliminate the troubles in the future. However a proper diagnosis of the wilting condition of plants grown in peat soils does not appear to be a simple matter for field men.

Our observations were made in the morning in order to exclude all types of day wilting. Thousands of plants were pulled and the disease could be readily determined in the field. To determine the probable cause of wilting in nearly 2000 acres of potatoes grown in the peat soils of California, laboratory examinations were made of all plants picked up in the field since wilting is sometimes associated with lesions on the ground line.

The standard media for isolation of fungi and bacteria were used throughout all investigations. The pathogenicity of the isolated organisms was proved by making inoculations into potato tubers.

Of the 129 plants carefully cultured in the laboratory the following organisms were recovered:

The author wishes to express his gratitude to Drs. M. W. Gardner and P. A. Ark of the Division of Plant Pathology of the University of California, for their kindness in permitting the use of laboratory facilities, which have made this investigation possible.

88	plants	*Rhizoctonia solani*.....	68.2	per cent
27	"	Black leg *Erwinia phytophthora*..	20.9	" "
6	"	Black leg and *Rhizoctonia solani*..	4.7	" "
4	"	Black leg and Ring Rot *Phytomonas sepedonica*	3.1	" "
4	"	Ring Rot *Phytomonas sepedonica*.	3.1	" "

It must be emphasized that in most cases (68.2 per cent) where the external appearance of the vine resembled a typical case of the black leg disease *Erwinia phytophthora, Rhizoctonia solani* was isolated in pure culture. A criterion used for diagnosing the disease as black leg was the description of the disease by Appel and Leach and the opinion of practical farmers. The black leg organism, *Erwinia phytophthora* in pure culture was isolated in 20.9 per cent of the cases whereas in 7.8 per cent of the cases it was associated with other pathogenes.

This survey of wilted plants grown under the conditions obtainable in peat soils, point to the need of a more careful and a more critical examination of plants in the field and, if facilities permit, laboratory tests must be performed to ascertain the causal agent.

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BENEFITS TO BE DERIVED FROM SOUTHERN CERTIFIED SEED TRIALS

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There are several benefits to be derived from the testing of various seed lots in the south, or in trade territory. The most important of these benefits is the greater knowledge gained regarding the general desirability of the various stocks which are being grown for shipment as certified seed. An opportunity is afforded to check freedom from disease, as well as the adaptability of various strains and varieties in various sections. In this way weaknesses in various lots can often be discovered, resulting in their elimination. Lots which have a desirable performance history for a period of years are, of course, worthy of further trial.

These tests are especially desirable for making readings in connection with virus diseases. Very often conditions are such in the producing state or area that accurate readings are difficult to make. Viruses often make themselves more apparent in trade territory than in the northern production areas. Should a tested lot be found wholly undesirable during the winter months, certification tags can be refused and the lot shipped as common, or at least the grower can be given definite knowledge regarding its undesirability for use another year, and have a chance to dispose of it and purchase new and better seed stock.

Nearly every producing section has a few pet troubles. In some places it may be late blight and in others it may be leaf roll. In still others, it may be rhizoctonia or some other disease. These tests afford an opportunity to detect the importance and effects of such diseases in trade territory. As a part of these tests, actual experiments with one or

several diseases may be consummated independently or cooperatively with officials in the trade territory, in order to determine the effect and even the means of counteracting the trouble.

Sometimes new or different diseases may be suspected or encountered. These tests provide a quick check-up on them. Occasionally physiological factors may enter upon the scene. In such a case, southern tests may be an important factor in determining the effect and control.

The fact that a plot affords a chance to get a concentrated observance and comparison of various lots is important. If one were to seek this information by visiting various fields, even in different areas, planted on different days, or planted on varying types of soil, comparisons could not be gained so accurately. Without question, a better understanding of one's own product, and a better understanding among the officials in the producing and consuming states will result. In this way a greater knowledge is gained by all who are interested.

Last but not the least, there is a great deal of satisfaction in being able to verify one's ideas concerning various lots. It gives added confidence to producers and officials in both the shipping and the receiving states.

The expenses of southern test plots are usually relatively high. The cost of assembling accurate samples, maintaining identity, transportation, and personnel salary increases expenditures. Unless the tests represent considerable volume costs might be prohibitive. In some instances cooperative plots with southern agencies might help reduce these costs.

The use of northern greenhouses for winter testing offers a fair, but less comprehensive substitute for southern test plots.

FERTILIZER AND NUTRITION STUDIES WITH THE POTATO IN 1941

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This report summarizes briefly the results of investigations published in 1941 on fertilizers, fertilization, rotations, green manures, cover crops and soil reaction with reference to the potato. Some references which have not been abstracted in this review are included in the bibliography with the literature citations for those who desire a fairly complete bibliography on this subject.

In a factorial experiment involving dates of planting, certified and uncertified seed, with and without fertilizer applications and several

spray materials, Hill (25) found that applications of 1,400 pounds 5-10-10 per acre increased yields from certified seed, 40 bushels, and from uncertified seed 12 bushels, compared with those receiving no fertilizer. When planted on the 22d of April the fertilized plots outyielded the unfertilized plots 46 bushels per acre; when planted on the 25th of May the former outyielded the latter by only 20 bushels per acre; and when planted on the 5th of June the difference in favor of the fertilized plots was only 7 bushels per acre. With certified seed planted on the 27th of April, fertilizer increased the yields 74 bushels per acre compared with the unfertilized; with uncertified seed the increase was 18 bushels per acre; with certified seed planted on the 25th of May fertilizer increased the yields 42 bushels per acre; with uncertified seed the increase was 7 bushels per acre. With certified seed planted on the 6th of June fertilizer increased yields 4 bushels per acre; with uncertified seed the increase was 12 bushels per acre in comparison with the unfertilized. Houghland and Strong (26) report that the 60:40 inorganic-organic N ratio gave higher average yields than the 80:20 ratio. The completely neutralized fertilizer produced higher yields than a similar mixture only 1/3 neutralized. There was little difference in the yields produced from soluble and insoluble sources of Mg. Complete neutralization of the fertilizer was more effective when soluble Mg was applied, but when the mixture was only 1/3 neutralized there was little choice between soluble and insoluble Mg sources. Fertilizers with 80:20 inorganic-organic N ratios produced better yields with soluble Mg, whereas the fertilizers with 60:40 ratios produced higher yields with Mg from an insoluble source. Complete neutralization was more effective with mixtures having an 80:20 ratio of inorganic-organic N than with those having ratios of 60:40. The use of neutral fertilizer over a period of 5 years showed no definite tendency to increase the initial pH (about 5.0) of the soil. The use of fertilizer only 1/3 neutralized lowered the pH from 5.0 to approximately pH 4.5 Watson (56) discussed the maintenance of soil fertility in England during the war period and compared the types of agriculture conducted in England and Germany before the war. In Scotland the most profitable fertilizer for potatoes without manure is 425 pounds sulfate of ammonia, 950 pounds superphosphate, and 275 pounds muriate or sulfate of potash; with manure, it is 400, 700, and 200 pounds per acre, respectively. Manure applied to potatoes produces better returns than when applied to any other crop in Scotland.

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Lockwood (32) discussed problems relating to proper rates of application, the most efficient ratios of N, P_2O_5 and K_2O in fertilizer mixtures, the relative merits of high analysis and ordinary analysis fertilizers, the effect of the use of stable and green manures on commercial fertilizer practice, and the effect of acid and neutral fertilizer mixtures for potatoes on limestone soils. Smith (51) discussed the fertilizer, soil reaction and rotation problems confronting potato growers in New York State. It has been shown that in most locations in the state, a 1-2-1 ratio is not sufficiently high in potash for maximum yields. In some cases, it has been demonstrated that best yields cannot be obtained with less than 1,500 pounds 4-8-12 per acre. Responses to manure on Bath gravelly silt loam soils have been remarkable. Short rotations are being recommended, with such green manure crops as silage corn, alternating with potatoes, doing very well in some locations. Corn as a green manure has reduced the amount of scab at some reactions and has increased potato yields. Russell and Garner (44, 45, 46), in reviewing the fertilization of potatoes in England, state that in most years 400 pounds sulfate of ammonia would profitably increase potato yields when phosphorus and potash also are added. In poor soil the effectiveness of N is enhanced by phosphate and potash; in more fertile soil, phosphorus still enhances the effect, though potash does not. Farm yard manure had practically no action on the effectiveness of sulfate of ammonia in heavy soils; only on light soils did any marked difference appear. Greatest increases in yields from N applications occur on heavy fens and least on light soils. Calcium cyanamide, ammonium bicarbonate and ammonium chloride are not as good sources of N for potatoes as is ammonium sulfate. Applications of 50 pounds P_2O_5 per acre have resulted in yield increases of 0.20 to 1.47 tons per acre. Farm yard manure depresses the effectiveness of superphosphate. The response to phosphate is greater on heavy soils than on light soils. Response to potash is more variable than to phosphate or nitrogen. The effectiveness of potash fertilizers is greatly reduced by farm yard manure. They have no evidence for the statement that light soils respond much better than heavy ones to potash, excepting only on the light and heavy fen. The heavy fen is the least responsive of all soils examined. Additions of $MgSO_4$ had no consistent significant effects on yields, whereas potash additions consistently increased yields in some instances as much as 75 bushels per acre. NaCl neither increased nor decreased yields. Chloride depressed yields in 54 of 66 experiments, the average reduction being about 8 bushels per 100 pounds chloride. The reduction in yield is larger on light than on heavy soils and in moderately dry seasons than

in wet ones. Yields from sulfate of potash are usually higher than from other sources of K. Yields were higher when commercial fertilizer was placed in the bottom of each furrow than when broadcast and plowed under. Granular fertilizers resulted in higher but not significantly higher yields than the powder form. Fifteen tons barnyard manure increased the yields 76 bushels per acre or about the same increase produced by 350 pounds $(NH_4)_2SO_4$. Increased increments of $(NH_4)_2SO_4$ increased yields about the same whether or not barnyard manure had been applied. Applying manure in the bottom of the furrow just before planting is the most effective method of application. Rotted manure and fresh manure resulted in equal increases in yield. Two tons of chopped straw per acre reduced yields. Increasing the proportions of straw in manure did not increase yields. Composted straw was inferior to manure. The increase in yield from poultry manure is 57 per cent of that from $(NH_4)_2SO_4$ supplying the same amount of N. Rape dust, fish meal, meat meal and malt culms are inferior to $(NH_4)_2SO_4$ when supplied in equal amounts of N.

Fertilizer treatment apparently has no relation to the incidence of disease or insect injury of potatoes. Loss of weight and amount of decay of potatoes are higher in those grown with manure and complete commercial fertilizer than in those grown without them, when stored in outdoor pits. Fertilized potatoes yield higher and average larger than those unfertilized. $(NH_4)_2SO_4$ increases yields but only in one-half the cases did it raise the per cent of marketable tubers. Potash and also manure markedly increase the proportion of marketable tubers. About 1,600 to 2,000 pounds of potatoes containing about 320 to 400 pounds starch equivalent can be obtained per 100 pounds $(NH_4)_2SO_4$, provided potash and phosphate are sufficiently supplied. This varies with rate of application, being lower at the higher rates. The increases due to superphosphate may be even greater than those due to nitrogen, but they are not so widespread and are more affected by soil and other conditions. Like N, phosphate increases both the size and the number of tubers, largely the latter. Potash increases yields mainly by increasing size of tubers. Manure increases both the yield and the percentage of marketable tubers. Applications of commercial fertilizer up to 1,200 pounds on some soils and 1,800 pounds per acre on other soils resulted in increased yields above any lower application. Potatoes can be grown as a first crop on newly plowed grass-land and should be fertilized much the same as on older cultivated land.

Mattingley (33) working in several areas in Victoria, Australia, obtained best results at Romsey, Musk, Wheatsheaf and Trentham from

300 pounds superphosphate plus 200 pounds ammonium sulfate per acre. At Beech Forest, best yields were obtained from 900 pounds superphosphate and 200 pounds ammonium sulfate per acre; at Neerim, highest yields were from applications of 600 pounds superphosphate, 100 pounds ammonium sulfate and 100 pounds potassium sulfate. At Toombullup and Newlyn, poor yields were obtained with no significant differences between treatments. Harrington, Iverson and Pollinger (23) found that phosphorus applied to potatoes resulted in earlier emergence and earlier growth of plants, increase in set of tubers, increase in yields, improvement in type and grade, better netting on the Netted Gem variety and better maturity and less skin slipping. Nitrogen used alone resulted in lower grades, poorer maturity and poorer netting. Nitrogen frequently is a deficient element and its use with phosphorus is necessary to give best results. Maturity and netting were much lower by potash applications, either when used alone or in combinations. Boron was found to be a deficiency element in some parts of western Montana. Gericke (19) showed that normal fertilization with stable manure was insufficient for maximum yields of potatoes. To produce a yield of approximately 333 bushels per acre, fertilization with K and N and either 30 tons manure or 53 pounds per acre of mineral phosphate such as Thomas phosphate was necessary. The phosphorus in the manure was less available than that in the Thomas phosphate, 88 pounds P_2O_5 in the form of the latter being equivalent to 253 pounds in the former. Increased applications of mineral phosphate up to 106 pounds P_2O_5 per acre improved the total yields and P and N assimilation of the plants. The starch yields were raised 21-31 per cent by the higher applications of P and the starch content of the potatoes could be improved as much as 1 per cent. As the starch content was increased the water content was decreased by the same amount. The average size of the tubers was also improved by the P fertilizing. A study of the relation of fertilization to scab infection showed that $(NH_4)_2SO_4$ tended to retard the susceptibility of the potatoes toward the disease whereas $Ca(NO_3)_2$ favored it. When the former was supplied as the source of N, no relation of source of P to scab decrease was observed.

Fitch (17) reported briefly on several fertilizer tests conducted on muck soils in Iowa. In Florida, Fifield and Wolfe (16) found that for mixtures to be applied at rates of about 1,500 to 2,000 pounds per acre there is no justification for increasing the analysis beyond 3 or 4 per cent N, 8 per cent phosphoric acid and 4 or 5 per cent potash. In most instances a 4-8-5 mixture in which 33 per cent of the nitrogen was derived from organic sources yielded as well as mixtures containing a

higher percentage of nitrogen so derived. Organic materials milorganite, blood and bone tankage and dried blood slightly outyielded cottonseed meal, cyanamid, fish scrap and urea. Urea and cyanamid showed up well in cost of fertilizer per bushel of potatoes. No significant differences in yield were obtained when sulfate of ammonia and nitrate of soda were compared as inorganic sources of N in a 4-8-5 formula containing 50 per cent of its N from organic sources. Likewise, no significant differences in yield were obtained between the sulfate and muriate forms of potash as sources of potash in a similar 4-8-5 fertilizer. Stable manure increased the yields slightly when applied at 6-8 tons per acre with commercial fertilizer but not sufficiently to justify the cost. One hundred pounds per acre of 65 per cent manganese sulfate is recommended annually for the first four years on new land. Applications of magnesium sulfate, copper sulfate, iron sulfate, iron citrate, borax, sulfur and $CaSO_4$ failed to increase yields profitably. Zinc sulfate did not consistently increase yields. Crowther and Yates (10) state that data from hundreds of experiments in England where manure had been applied show that potatoes respond to 120 pounds of $(NH_4)_2SO_4$ applications in the order of 12 per cent. To 300 pounds superphosphate per acre, the response was about 10 to 25 per cent; and to 100 pounds sulfate of potash, the increase was 18 per cent without, and 6 per cent with manure. There are positive interactions between nitrogen and phosphate and between phosphate and potash, but there is little interaction between nitrogen and potash. The optimal application of sulfate of ammonia in money returns has been 300 to 500 pounds per acre. The current level of nitrogenous manuring is too low, particularly where dung is also added. Potash is particularly short in England, but as potatoes respond so markedly to it, it is recommended that potash still be added in fairly large amounts.

Bushnell (7) found that the application of suitable carriers of P or N to the well oxidized silt loam subsurface soil of a Wooster silt loam increased the quantity of roots in this subsoil. Among the materials causing this increase were the Ca phosphates, mono- and diammonium phosphates, $Mg_3(PO_4)_2$, KH_2PO_4, superphosphate, urea, Ammo-phos, ammonium nitrate and sulfate and commercial $CaCN_2$. Ca, Mg, K and Na nitrates, $CaCO_3$, $CaSO_4$ and mono- and disodium phosphates were ineffective in increasing the quantity of roots. An increase in the quantity of roots in the subsurface soil was not consistently accompanied by an increase in yield of tubers. Dunn (13) found no injurious effects on rate of emergence or yields by placing fertilizers from ½ inch to 1 inch from the seed pieces. Cut seed placed in contact with fertilizer showed

definite injury to the plants. Larson (31) presents data on various methods of placement and several types of fertilizers. Edgar and Cummings (14) have reviewed some of the previous work on the placement of fertilizers.

Innes (28) found that on the red dirt soils of the Devon area, 200 pounds K_2SO_4 can be substituted for 600 pounds of fish fertilizer without loss of yield or quality of potatoes and without any loss in residual fertilizing values. Innes (27) concluded that the improvement in yield and grade of potatoes on red dirt soils noted with both fish fertilizer and inorganic fertilizer is due solely to the K content of these fertilizers.

Brasher (3) found that the longer the fertilizer application was delayed after planting, the lower the yield. An application of 1,500 pounds per acre 5-10-10 at planting time produced higher yields than when 1,000 pounds or 500 pounds were applied at planting time and part or all of the remaining 500 or 1,000 pounds applied at time of emergence or blossoming time.

Smith and Nash (52) found, in general, a decrease in specific gravity and dry weight percentage of tubers as the fertilizer applications were increased from 1,000 to 3,000 pounds 4-8-8 to the acre, irrigated tubers being lower at each rate of application than those not irrigated. In general, there was an increase in the degree of blackening of tubers as the rate of fertilizer application increased. Tubers from plants receiving heaviest potash and nitrogen applications had lower specific gravity, lower dry weight percentage and lower texture rating than tubers receiving least potash and nitrogen. With the same cations the chloride form of salt produced tubers of lower specific gravity than the sulfate form. $CaCl_2$ applications produced tubers of higher specific gravity than equal applications of KCl. Cowie (9) mentions the nutrient condition of the soil as one of the factors that produces chemical changes in cooked potatoes. A high N and low K ratio in the soil or fertilizer will cause blackening of cooked potatoes. Nehring (38) reports that the influence of single elements on vitamin C content has not been established. The vitamin C content is not lowered by complete mineral fertilization as compared with fertilization with manure. The type of soil seems to be of greater significance than fertilization. Scheunert *et al* (47) claim that the vitamin C content of potatoes is unaffected by the nature of the fertilizer used and even after long periods of time remains about 11-13 mg. per cent. Shortly after the potato crop is harvested the vitamin C. content is 17.29 mg. per cent and gradually decreases to approximately 7 mg. per cent in June.

Westover (57) found that the effect of fertilizers on the shape of

tubers was influenced markedly by climatic conditions—especially soil moisture. High N treatment caused tuber elongation with a lesser effect on tuber width. High phosphorus treatment influenced length much more in years of adverse growing conditions, whereas tuber width was affected most under favorable seasonal conditions. Potash had little effect on shape under unfavorable growth conditions, but contributed more to width under favorable conditions. Sugawara (53) reports higher respiration rates and respiratory quotients with potash deficiencies. Reducing sugars also increased in the tubers and the activities of diastase, invertase, oxidase, peroxidase and ereptase increased, while catalase decreased and peptase was not changed. The content of ascorbic acid in tubers increased with increasing amount of potassium applied to the soil. Antykov (1) noted that the starch content of potatoes was decreased by the addition of mineral fertilizers in the spring.

Teakle, Morgan and Turton (54) found, in western Australia, on neutral sandy swamp soils that potatoes gave excellent responses to copper sulfate used at the rate of 5-10 pounds per acre. Row and broadcast applications gave similar increases. Potato yields on marly soils were increased by additions of manganese and further increased by copper additions, although copper without manganese had no beneficial effect. Ten pounds of manganese sulfate and 5 pounds of copper sulfate are recommended for potatoes on these soils. Zinc sulfate, magnesium sulfate and borax did not increase yields. Jones and Brown (29) have described the symptoms in potato plants of deficiencies of nitrogen, phosphorus, potassium, magnesium, calcium, boron, manganese, sulfur, iron, copper, and zinc and present methods of preventing or correcting these deficiencies. Hawkins, Chucka and Brown (24) have found in Aroostook County, Maine, that comparatively small amounts of boron and nickel added to fertilizer may be toxic to potatoes. The addition of small amounts of zinc indicated a tendency, though not significant, to increase potato yields. Manganese, iron and copper had little or no effect on potato yields. Neuweiler (39) reports improved quality of Flava and Ackersegen potatoes from boron treatment in Switzerland.

Mikhailov (34) obtained substantial increases in yield by fertilizing with vivianite or peat containing it. Plants thus fertilized matured 3-5 days earlier than those receiving only stable manure and gave about ⅛ higher yield. During a 4-year period vivianite increased the yield of Hollander potatoes 43 per cent. Friedrich (18) states that potato tubers soaked 24 hours in solutions of heteroauxin, beta indolebutyric acid and alpha naphthyl-acetic acid increased the ratio of root to tops. Sometimes

the root system was actually greater than in the control and sometimes it was less. Molotkovskii and Porutskii (36) found that smearing potato tubers with a paste of 50 per cent pregnant mare urine promoted growth rate and development of plants. Stronger concentrations were less effective and even retarded the growth of the plants. Porutskii (41) injected urine from a pregnant mare into or near the eyes of potato tubers. Germination and bloom were earlier and the yield and starch content of the crop increased by the urine hormone injections. Pastes were prepared from urine of pregnant women and pregnant mares and applied to potato eyes. The treated plants were superior to and earlier than the untreated controls. Similar growth acceleration was obtained by use of solutions of extracts of urine from non-pregnant women and mares.

Ripley (43) in northern Ontario and at Ottawa found that summer fallow preceding potatoes was unfavorable. Nitrates were low in soils following potatoes and also crops following potatoes usually did not yield well. Carbon dioxide production in incubated soils was higher following alfalfa, red clover, timothy and summer fallow than after potatoes, and followed the same trend as crop yields. Coates (8) found that there are organic carbon losses in the soil in a 3-year rotation of potatoes, oats and clover when all crops are removed. Basic fertilizer treatment was one ton per acre of 4-8-7. Additions of lime and fertilizers high in phosphoric acid reduced organic carbon losses the most. The 4-8-7 plus lime treatment was not so effective as the 4-16-7 treatment in producing high yields but it was more effective in maintaining the organic carbon level. Dean (11), mentioned some rotation systems which are practiced in New York State.

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EFFECT OF NUMBER OF PLANTS PER HILL ON THE YIELD OF POTATOES IN OHIO

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Numerous experiments on the rate of planting potatoes have shown that increasing the size of the seed pieces increases the average number of plants per hill. The increase in plants to the hill, in turn, increases the number of tubers per hill, and although the average size of the tubers is reduced, there is usually an increase in yield. The inference has sometimes been drawn that any other method of increasing the number of plants to each hill would similarly increase the yield. On the other hand, Appleman (1), studying the decline in apical bud dominance, noted that, as the number of sprouts increased, the individual sprouts were less vigorous.

In connection with studies pertaining to the relation of age of tubers to their type of sprouting under field conditions (3) the question arose as to what number of plants per hill would produce the highest yield. From common observation in Ohio our potato fields vary from one to five plants in the hill, and the hills with the fewest plants have the fewest and largest tubers. Typical differences in hills varying from one to three plants of Russet Rural are illustrated in figure 1. The difference in average size of tubers is apparent, but it is difficult to determine which hill has the highest yield.

DATA

In 1935 and 1936, 100 hills of Russet Rural were harvested and weighed individually. These data are shown in table 1. In the yield of size A tubers, the two-plant hills averaged slightly higher than the others.

TABLE 1.—*Data of Russet Rural potatoes grown on silt loam at Wooster, classified according to number of plants per hill.*

Plants per Hill	Yield per Hill			Size A Tubers*		Hills in Each Class
	Size A*	Size B	Total	Number per Hill	Average Weight	
	Lb.	Lb.	Lb.		Lb.	

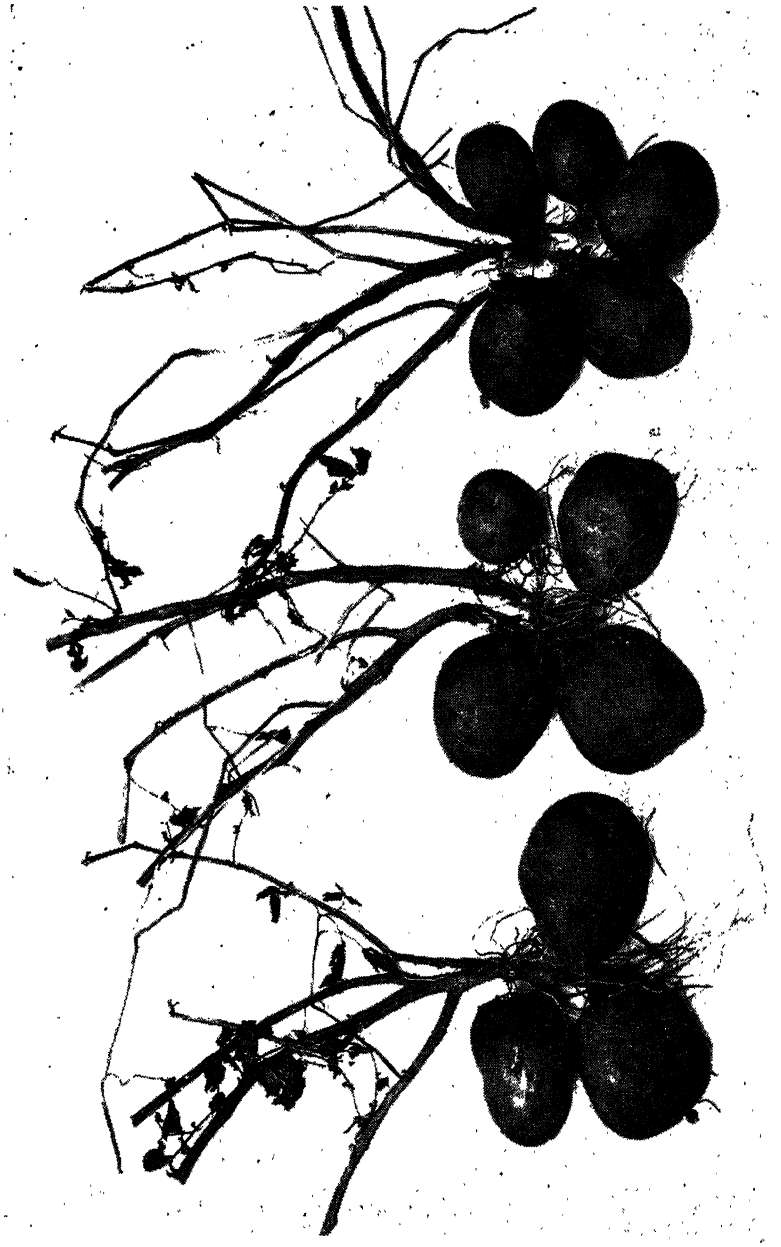

FIG. 1. Typical tuber production on one-, two- and three-plant hills of Russet Rural at Wooster, Ohio

Planted May 29, 1935

1	1.32	0.15	1.47	4.69	0.281	32
2	1.63	0.32	1.95	5.21	0.313	51
3	1.53	0.43	1.96	5.40	0.283	15
4	1.40	0.55	1.95	6.00	0.233	2

Planted June 20, 1936

1	0.92	0.07	0.99	2.44	0.377	17
2	1.03	0.09	1.12	3.32	0.310	29
3	1.01	0.18	1.19	3.72	0.272	38
4	1.00	0.24	1.24	3.60	0.278	16

*Size A tubers are those retained on 1⅞-inch screen, size B are those from 1⅞ to 1½ inches.
Seed pieces 1.6 ounce—spaced 12 inches in rows 32 inches apart.

In the following five season, 200 hills of Irish Cobblers were similarly weighed and classified, as noted in table 2. The average yield of size A tubers was practically the same from the hills with two, three, or four plants, and significantly higher than the average yield of the one-plant and five-plant hills.

As anticipated, the yield of size B tubers markedly increased with the number of plants to each hill. Likewise, the average weight of the individual size A tubers declined with the increase in plants per hill.

TABLE 2.—*Data of Irish Cobbler potatoes grown on sandy loam at Washington County Truck Experiment Farm, southeastern Ohio.*

Plants per Hill	Yield per Hill			Size A Tubers		Hills in Each Class
	Size A Lb.	Size B Lb.	Total Lb.	Number per Hill	Average Weight Lb.	
Planted April 6, 1937						
1	1.36	0.07	1.43	3.56	0.382	23
2	1.46	0.09	1.55	4.36	0.335	85
3	1.44	0.17	1.61	5.05	0.285	64
4	1.27	0.24	1.51	5.24	0.242	21
5	0.90	0.48	1.38	4.06	0.222	7

Planted March 29, 1938

1	1.26	0.08	1.34	4.50	0.280	8
2	1.25	0.13	1.38	4.90	0.255	47
3	1.33	0.18	1.51	5.24	0.254	65
4	1.25	0.27	1.52	5.46	0.223	50
5	1.16	0.29	1.45	5.51	0.211	30*

Planted April 3, 1939

1	0.83	0.06	0.89	2.48	0.335	46
2	0.95	0.08	1.03	3.16	0.301	98
3	0.89	0.13	1.02	3.43	0.259	42
4	1.05	0.14	1.19	4.00	0.262	10
5	0.80	0.24	1.04	3.60	0.222	4

Planted April 5, 1940

1	1.01	0.06	1.07	3.37	0.300	26
2	1.10	0.12	1.22	4.14	0.266	87
3	1.17	0.21	1.38	4.79	0.244	58
4	1.16	0.35	1.51	5.35	0.217	21
5	1.13	0.50	1.63	5.57	0.203	8

Planted April 3, 1941

1	1.10	0.08	1.18	3.12	0.353	27
2	1.23	0.11	1.34	5.03	0.245	79
3	1.33	0.22	1.55	5.78	0.230	64
4	1.28	0.34	1.62	6.08	0.211	24
5	0.99	0.53	1.52	4.78	0.207	6

Average of 5 seasons**

1	1.11	0.07	1.18	3.41	0.330	26
2	1.20	0.11	1.31	4.32	0.280	79
3	1.23	0.18	1.41	4.86	0.254	59
4	1.20	0.27	1.47	5.23	0.231	25
5	1.00	0.41	1.41	4.70	0.213	11

*Includes four hills with six plants.

**Simple averages, not weighted.

Seed pieces, 1.6 ounce, spaced 12 inches in rows 32 inches apart.

Discussion

Although two to four plants per hill gave the highest yield of tubers over 1⅞ inches diameter in this test, this will not always hold as a general rule. Quite to the contrary, these data (table 2) themselves show that if all the tubers over 1½ inches in diameter were saleable (as sometimes holds in seed production) the hills with three to five plants would produce the highest yield. Conversely, although not demonstrated by any data given here, if a grading screen 2 inches or larger had been used, and only the large tubers were saleable, the peak of the yield would tend to shift toward the hills with fewer plants.

Growers ordinarily do not think in terms of number of plants per hill, but are well aware that the distance between the hills affects the average size of the tubers. In actual practice, then, the spacing of the hills becomes well adapted to the types of hill that are most likely to appear. To explain this more clearly, the number of hills of each type for each season is given in the right-hand column of table 2. The hills with two or three plants consistently predominated and, at the spacing of 12 inches between hills, which is a common distance in Ohio, the hills with two and three plants produced the maximum yields of size A tubers.

The general conclusion, then is, that the number of plants per hill, within the ordinary range of one to five, is, itself, not an important factor in yield of potatoes. On the other hand, it may be of some importance to recognize that the age of the seed is a factor in the number of plants per hill that may be expected (2), and to modify the spacing of the hills accordingly. For example, in Ohio, our Russet Rural potatoes average two plants or less per hill in the April plantings and a 9-inch distance between the hills is advocated, whereas if the same seed is held until June it will average about three plants per hill, at which time we advocate a distance of 12 inches.

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THE AGE OF MAXIMUM REPRODUCTION VIGOR IN IRISH COBBLER SEED POTATOES

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In 1924 Appleman (1) pointed out that apical bud dominance in potato tubers gradually diminishes during dormancy, so that the longer the tubers are held in storage the larger will be the number of buds that will sprout after the seed pieces are planted. He observed that, after prolonged storage, the individual sprouts were slender and weak, and he, therefore, logically concluded that a high degree of apical bud dominance might be a practical index of vigor of seed potatoes.

In actual field plantings, however, apical bud dominance has almost invariably diminished to the stage where ordinary seed pieces average two or more sprouts to each seed piece (2). Even tubers from late plantings, immature at the time of frost in the fall, and planted early the following spring, usually produce more than one plant for each seed piece. Seed tubers from a late planting, however, are more apically dominant than tubers from an earlier planting, that is, fewer plants develop from the immature seed.

Prior to the discovery of the virus diseases, considerable evidence had accumulated indicating a superiority of immature seed from late plantings, thus supporting Appleman's hypothesis, but after the infectious nature of the viruses was known, the superiority of late-planted seed was attributed to its comparative freedom from these diseases. In the early development of methods of producing certified seed the time of planting was disregarded, except in states where the season is long enough to produce a distinct fall crop of early varieties. In New Jersey, Maryland, and Kentucky the fall crop has been the only crop eligible for certification.

If late planting results in seed of superior vigor, the fall crop seed would be expected to outyield seed from the northern states. Comparative tests have shown that under some conditions this is true. The data from work conducted by Martin, Peacock and Lombard (5) are summarized in table 1. Jehle and Walker (4), in their studies, observing the slowness with which the fall-crop seed emerged, heated Maryland seed before planting and obtained a difference of nearly 25 bushels per acre in favor of the fall-crop seed.

TABLE 1.—*Yield from New Jersey fall-crop Cobblers compared with certified seed of the same strain from Maine.*

	Four-year Average Yield, in Bushels per Acre					
	In New Jersey		In Connecticut		In Maine	
	Primes	Total	Primes	Total	Primes	Total
Fall-crop seed	81.3	113.8	188.6	211.2	287.4	312.4
Maine seed	69.0	109.6	181.9	206.7	290.8	315.3

In Ohio, the late June planting of Russet Rural seed plots has been advocated since 1929. Some of the data showing the value of late-planted seed are given in table 2. Seed thus produced in Ohio often proved superior to the certified Russet Rural seed from Michigan (3).

TABLE 2.—*Effect of date of planting the preceding year on the yield of Russet Rural at Wooster, Ohio.*

Date of Planting Seed Plot in 1926	Test Planted April 12, 1927		Test Planted May 24, 1927	
	Plants per Hill	Bushels per Acre	Plants per Hill	Bushels per Acre
April 20	2.0	269	3.0	241
May 20	1.9	264	2.9	249
June 21	1.6	284	2.5	266

So, for the past decade, the planting of Russet Rural seed plots in late June has become a standard practice in Ohio, and many of the growers in Michigan who grow certified seed for the Ohio trade have likewise delayed their planting until June.

TESTS OF IRISH COBBLER SEED FROM SUCCESSIVE PLANTINGS

In 1932 a similar experiment was started with Irish Cobbler potatoes for the purpose of determining the proper time of planting for the production of seed for southern Ohio. The plan was to plant seed plots at monthly intervals from early April to mid-July, and to test this seed the following year at the Washington County Truck Crops Experiment

Farm, located near Marietta, in southeastern Ohio. The early April seed plot was grown at the Washington County Farm; the early May and early June plots at Wooster; in northern Ohio, and the mid-July planting was grown either in Hamilton County or Washington County in southern Ohio.

Each year, all lots were stored at Wooster in a basement which could be warmed whenever the temperature dropped below 36° F. During the last week in March they were sent by trucks to the Washington County Experiment Farm near Marietta, and planted as soon as the soil was in proper condition—in every season before the 6th of April. For comparison, Maine certified seed, purchased from local dealers, was included. Precautions were taken to cut the seed into uniform pieces weighing ten to the pound. The planting was triplicated in 80-foot rows, 32 inches apart, with hills 12 inches apart in the row.

Perfect stands were obtained every season, except for occasional plants that were infected with rhizoctonia. During some seasons, however, a small percentage of virus diseases was evident, but since virus

TABLE 3.—*Yield of Irish Cobbler variety from seed grown by planting at approximately monthly intervals in Ohio—compared with certified seed from Maine. (Tested at Washington County Farm; planted about April 1.)*

Yield in Bushels per Acre, No. 1 Size Tubers

Year of Test	Ohio-grown Seed				Maine Certified Seed
	From Early April Planting	From Early May Planting	From Early June Planting	From Mid-July Planting	
1933	162	183	184	180	183
1935	366	383	390	358	413
1936	73	86	86	85	84
1937	292	353	347	313	363
1938	263	304	317	277	262
1939	157	191	154	177	194
1940	245	231	233	243	242
1941	202	301	**	291	205
Average*	223	247	244	233	248

*Not including the 1941 data because the Maine seed gave an unexplained low yield.

**Not included in the 1941 test.

diseases are, at times, difficult to detect, the counts are not reported here. Possibly the only serious infection occurred in 1941 when practically all the plants from the April seed and those from the Maine sample were below normal in size. This dwarfing in size we attributed to an unidentified virus disease.

As shown in table 3, none of the Ohio-grown lots averaged higher in yield than the certified seed from Maine. On the other hand, the seed from the early May plantings gave practically the same average yield as the certified seed, and the yield from the June-planted seed was not significantly lowered.

Discussion

The conclusion to be drawn is that the Irish Cobbler seed potatoes that are of most value for planting on the 1st of April are those from lots planted during May or early June of the preceding season. Since the usual time for planting potatoes in Maine is during the latter part of May or the early part of June, and the fact that the Maine seed averages as high in yield as any of the Ohio lots, helps us to support this deduction. In other words, the tentative generalization may be drawn that Irish Cobbler tubers are at an optimum age for planting from 10 to 11 months after the seed crop was planted.

The generalization may not apply, of course, to other districts or to seed stored at a lower temperature. In Ohio, however, experience has shown that the results with Irish Cobbler agree with those of the Russet Rural variety. Russet Rural tubers also appear to be at an optimum age for planting 10 to 11 months after the date the seed field was planted.

The type of sprouting of the two varieties at this age is not identical. Russet Rural planted at Wooster averaged less than two plants to the hill from seed pieces weighing 1.6 ounce, whereas the Irish Cobbler in this experiment has averaged nearly three plants per hill.

In the course of this experiment, no attempt was made to determine accurately the physiological age of the tubers by detailed records on either the date of setting in the field or the break in the rest period in storage. Incidental observations, however, showed the typical sequence in the development of tubers in the early May plantings to be as follows: Tubers set about the 15th of June mature in the field about the middle of August and terminate their rest period about the middle of November. These tubers are at a stage of maximum reproductive vigor by late March—about 9 months after the date of setting, 7 months after harvest, and 4 to 4½ months after the end of the rest period.

The data of this experiment do not support the hypothesis that a high degree of apical bud dominance is an index of productivity in seed potatoes. Apical dominance begins to diminish about the third month after the end of the rest period. These data indicate that the maximum productivity is at the stage where 1½-ounce seed pieces produce, as a rule, two to three sprouts.

Conclusions

Since the data presented here indicate that the best age for planting seed potatoes is 10 to 11 months after the seed field was planted, our producers of certified seed, when offering seed for sale, might render a service to buyers by reporting the date of planting. Townsend (6) in Florida, working with the problem of obtaining suitable Bliss Triumph seed for fall planting, has gone a step further and suggested that the dates of both planting and harvesting be required on the certification tags.

From our work, we conclude that the spring crop of Irish Cobbler potatoes from northern Ohio is suitable for planting for seed in the southern counties. This work should be of local interest in Ohio. Since Ohio is far from any district where large amounts of certified early varieties are produced and the cost of seed is correspondingly high, it is probable that some effort will be made to produce part of the Ohio seed requirements in the state.

Summary

Over a period of 8 years Irish Cobbler potatoes were planted at monthly intervals from April to July. The seed from these various plantings were planted about the 1st of April, the following year in southern Ohio. The most productive seed was produced from seed plots that were planted in the early part of May and early June. It is concluded that, under the conditions of the experiment, Irish Cobbler tubers are at an optimum age for planting 10 to 11 months after planting the preceding season. The spring crop of northern Ohio, that was grown from certified seed, proved very suitable for early planting in southern Ohio.

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RING ROT IN VOLUNTEER PLANTS

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Bacterial ring rot was observed for the first time in Maine in 1932. The disease was abundant in several fields located near Fort Fairfield in Aroostook County.

Since the discovery of ring rot in Maine, the writer has attempted to learn whether the causal organism may be overwintered in the soil and infect the crop which is planted the following season.

NON-SURVIVAL OF RING ROT ORGANISMS IN FIELD SOIL

Healthy seed potatoes have been planted each year from 1934 to 1940 in fields which during the previous season produced a badly diseased crop. From two to eight plots were grown each season. In 1939 and 1940, one tuber from each hill in the different plots was saved and grown the following year to make certain that no slightly infected plants had escaped notice. In no case during the seven years has there been evidence that the disease was carried over the winter in the soil. No volunteers were observed to be present in these fields.

In an additional experiment, 50 large clay tiles, 14 inches square and 36 inches deep, were submerged in the field the first week of October and filled with one or another of the different types of potato soil commonly found in Aroostook County. The soils used for this experiment varied from a dark Washburn loam, containing a high per-

centage of organic material, to a light gravelly Caribou loam which was low in organic matter.

About 10 pounds of tubers infected with ring rot were worked into the top 12 inches of the soil in each of the clay tiles. Twenty-five of the tiles contaminated with ring rot tubers were covered with several inches of straw mulch to serve as some protection against heavy frosts, and the remaining 25 tiles of soil were left unprotected throughout the winter.

A Green Mountain tuber and an Irish Cobbler tuber were planted the following spring in each tile of soil. The plants and potatoes that developed in the tiles were examined for the presence of ring rot during the growing season and at time of harvest. All of the tubers produced in the experiment were planted the following spring to make certain that the disease had not escaped notice during the previous examinations.

There was no evidence that the ring rot disease had survived the winter in the soil in the tiles.

Survival of Ring Rot Bacteria through Winter in Diseased Tubers Left in the Field

It has appeared that ring rot might be perpetuated in the fields of Aroostook County in volunteer plants developing from infected tubers left in the field at digging time. Data, however, were needed to demonstrate this.

During the harvesting seasons of 1938 and 1939, slightly infected tubers were planted six to eight inches deep in the soil in fields near Presque Isle. All these potatoes were frozen in the soil during the winter and no plants resulted.

In 1940, diseased Katahdin potatoes were planted during the harvesting season in four fields near Presque Isle. The tubers were put into trenches about six inches below the surface of the soil and covered to the surface level. In addition to this, part of each lot was covered with a shallow layer of weeds and potato tops.

Plants from the diseased tubers did not emerge until approximately the first week of August, 1941, and the growth of the plants was much retarded. The plants that developed were examined for the presence of ring rot at different times during the growing season.

It may be noted from the data in table 1 that 65 to 82 per cent of the tubers apparently survived and produced plants and 42 to 57 per cent of the tubers planted produced plants with ring rot.

The writer also examined some commercial fields for evidence that ring rot had developed from volunteer plants. In two of the fields ex-

TABLE 1.—*Ring rot in plants developing from diseased tubers which survived in the field during the winter of* 1940-1941.

Field No.	Protection[1]	No. Tubers Planted	Plants Produced	Tubers Whose Plants Developed Ring Rot[2]
			Number	Per Cent
1	Protected	100	65	45
	Not Protected	100	71	51
2	Protected	200	149	51
	Not Protected	200	135	46
3	Protected	100	82	42
	Not Protected	100	80	57
4	Protected	200	150	52
	Not Protected	200	147	53

[1]All tubers were placed in a trench six inches below the soil surface and covered with soil to the surface level. Part of each lot was further covered with 2 inches of weeds to serve as partial protection against cold.

[2]Per cent based on number of diseased tubers that were planted, not on plants produced.

amined, he found that ring rot had developed from diseased tubers left in the field during the previous harvest. It is ironical that in both of these cases the diseased volunteer plants were found in seed plots where the grower had taken special care to secure disease-free seed stock. It is obvious that these growers gained very little by planting disease-free seed stock because it could easily become contaminated from any diseased tubers that might be produced by the diseased volunteer plants.

CONCLUSION

The writer has evidence that the causal organism of ring rot did not remain visible through the winter in the soil of certain fields that produced a badly diseased crop. This, however, does not prove that the ring rot organism may not survive the winter in the soil under some conditions. The disease was proved to be perpetuated in the field in infected tubers which survive the winter and produce volunteer plants. These may contaminate any disease-free stock that may be planted in the same soil.

Growers are advised to plant their seed plots on land which was not planted to potatoes the previous year. They would do well to go over the prospective seed plot area the year before it is to be used for this purpose, and to make certain that all volunteer potato plants are destroyed.

A HISTOLOGICAL STUDY OF HOLLOW HEART OF POTATOES[1]

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Moore (1926) observed that the incidence of hollow heart increased rapidly in the later stages of tuber growth—an indication of a short developmental period similar to that of external growth cracks. The more recent observations of Krantz and Lana (1942), however, point to an early inception of hollow heart followed by enlargement of the cavity concurrent with enlargement of the tuber. Any final decision as to which of these two pictures is correct must rest on a histological study of this physiological disorder.

That the disorder is physiological is indicated by the following facts: (1) No causal organism has been found associated with it. (2) Attempts to transmit the disorder have failed (Wenzl, 1939). (3) The disorder apparently does not progress after the tuber has reached full size. (4) There is no external sign of infection. (5) The affected cells are farthest removed from the vascular system through which pathogenes may be transmitted. (6) Plants from affected tubers produce just as healthy tubers as plants from unaffected ones, under favorable environmental conditions (Wenzl), 1939).

In order to study the development of hollow heart, tubers of the Cobbler variety were examined at successive harvests made from the 24th of July to the 17th of September. The potatoes were planted at Grand Rapids, Minnesota, on the 15th of May. Each tuber was weighed, then cut open and examined for hollow heart. Of the 2818 tubers examined, 65 were found to be affected in different degrees as shown in table 1. The following arbitrary system of grading the injury was adopted:

1 = necrotic patch surrounded by wound cambium.
2 = hollow up to 5x10 mms.
3 = hollow from 5x10 mms. to 10x20 mms.
4 = hollow greater than 10x20 mms.

Hollow heart tubers occurred in every harvest, though only the early stages were observed at first, as indicated in table 1. The absence

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TABLE 1.—*Incidence of hollow heart at different dates of harvest.*

DATE	Total No. Tubers Examined	HOLLOW HEART TUBERS													
July 24	152	Tuber wt. (gms.)	15.3	25.0	28.9	29.9	65.0	73.6	80.8						
		Hollow Heart stage	2	2	2	2	2	2	2						
August 6	285	Tuber wt. (gms.)	6.1	12.1	12.8	22.7	23.5	33.9	48.1	54.7	55.8	192.0	210.0		
		Hollow Heart stage	1	1	1	1	1	1	2	2	1	3	3		
August 13	288	Tuber wt. (gms.)	1.8	19.5	109.1										
		Hollow Heart stage	1	1	1										
August 20	563	Tuber wt. (gms.)	2.0	5.6	10.7	11.4	58.5	67.8	68.5	83.5	92.6	109.0	121.4	137.8	195.8	208.8
		Hollow Heart stage	1	1	1	1	3	1	2	3	2	2	1	4	2	4
August 27	297	Tuber wt. (gms.)	54.3	88.0	123.7										
		Hollow Heart stage	1	3	2										
Sept. 3	298	Tuber wt. (gms.)	63.8	77.9	91.6	95.7	108.2	115.7	120.4	228.0	295.9				
		Hollow Heart stage	3	2	2	3	3	2	3	3	4				
Sept. 10	317	Tuber wt. (gms.)	49.5	115.4	126.8	194.6	201.3	263.0							
		Hollow Heart stage	2	2	1	3	3	3							
Sept. 17	618	Tuber wt. (gms.)	55.2	64.5	90.7	91.6	96.5	96.6	99.3	101.0	111.5	122.1	132.0	160.4	
		Hollow Heart stage	1	2	1	2	1	2	2	2	3	2	3	4	

of stage 1 in the first harvest may conceivably have been due to oversight, since at this stage all that is visible to the naked eye is a brown necrotic spot about 1 mm. in diameter. But after recognizing this stage for the first time (in the second harvest), there was no further trouble in detecting it. Though the fully developed hollows (stage 4 and usually 3) were found only in large tubers and the earliest stage in small tubers (ranging, however, from 1.8 to 126.8 gms.), the hollow heart stage paralleled tuber size only in a rough way. The incidence of hollow heart was four times as great in the first as in the last harvest. This negates the commonly held belief that hollow heart is initiated toward the end of the growing season. However, the last harvest consisted of two treatments, only one of which corresponded to the first harvest. When these two similar series are compared, the incidence in the first harvest is still double that of the last. Furthermore, treatments that were found to affect the incidence of hollow heart did so only if applied early in the summer (Krantz and Lana 1942). Consequently, even in the case of those tubers affected with hollow heart in the late harvests, the disorder probably had originated early in the summer.

The first observed stage of the hollow heart consisted of a group of several dead, brown cells in the pith, some still containing starch grains (Fig. 1). Surrounding the dead cells were several rows of practically starch-free cells. Some cell division had already occurred in this clear region. Later (Fig. 2), the group of dead cells was completely surrounded by a cambium layer of several rows. Sometimes the dead region was larger and incompletely surrounded by cambium (Fig. 3). At a later stage (Fig. 4), a small cavity had formed, surrounded almost completely by a row of dead, brown, collapsed cells whose structure was now unrecognizable. This row was ruptured at some spots. Just beyond were several rows of living cambium cells. Beyond this were several rows of relatively starch-free cells. At a still later stage (Fig. 5), the cavity was now larger and somewhat more elongated in the short axis of the tuber. Even at this stage, the wound cambium cells occurred in distinct radial columns, indicating that only periclinal divisions were involved. Neither the dead layer of cells nor the wound cambium layer completely surrounded the cavity. In those regions where they failed to do so, some elongated or spherical cells protruded into the cavity. Finally (Fig. 6), when the cavity had reached full size, nearly the whole surface was lined with these living, tylosis-like cells. Some of these cells appeared to have just divided, the nucleus of each daughter cell lying against the cross-wall. These cells were frequently larger than the tissue cells adjacent to them. They were sausage-shaped,

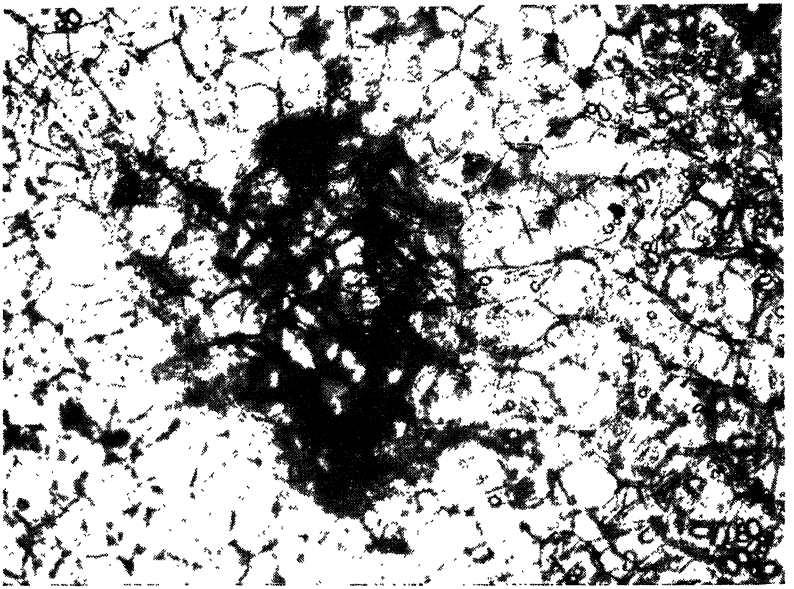

FIG. 1. First stage in hollow heart formation. Tuber weight, 1.8 gms.

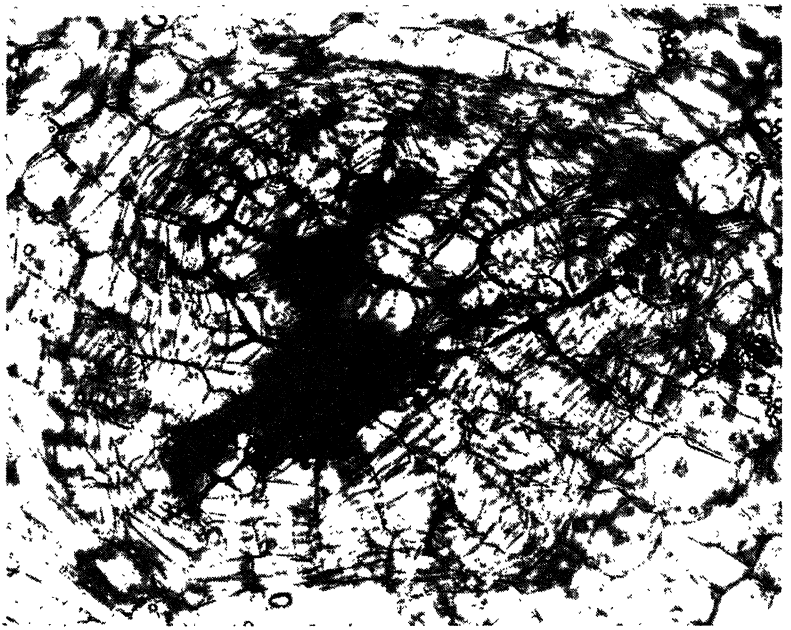

FIG. 2. First stage in hollow heart formation
Tuber weight about 10-20 gms. 140x.

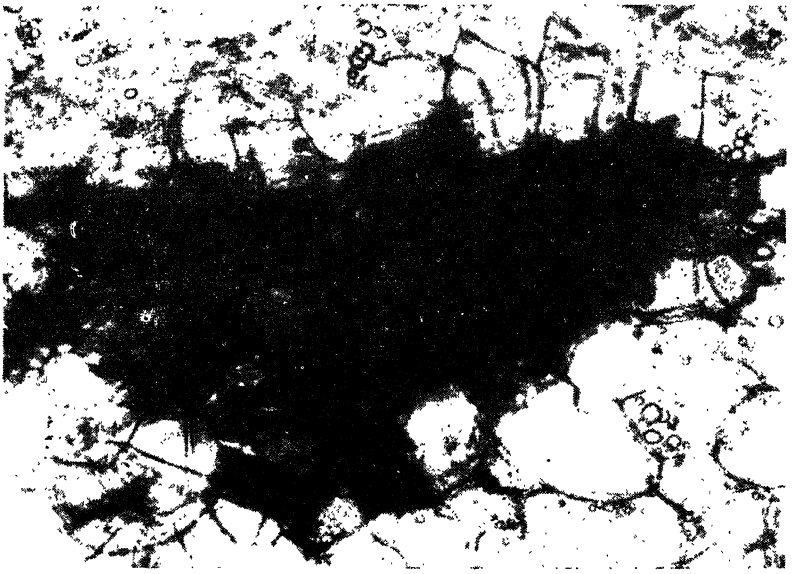

FIG. 3. First stage in hollow heart formation.
Tuber weight, 55.8 gms. 140x.

FIG. 4. Small hollow (about 3 mms. diam.).
Tuber weight, 54.7 gms. x40.

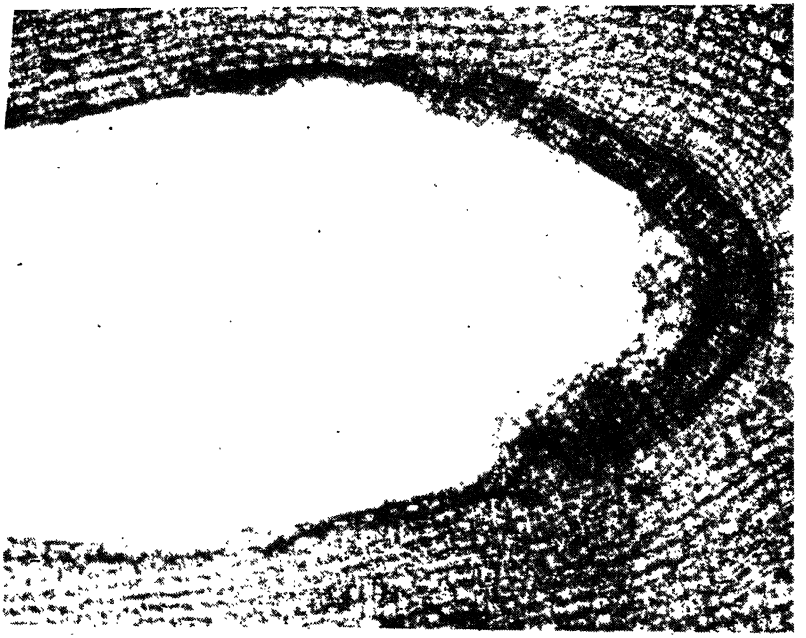

FIG. 5. Hollow about 7 x 10 mms. Tuber weight, 192 gms. 20x.

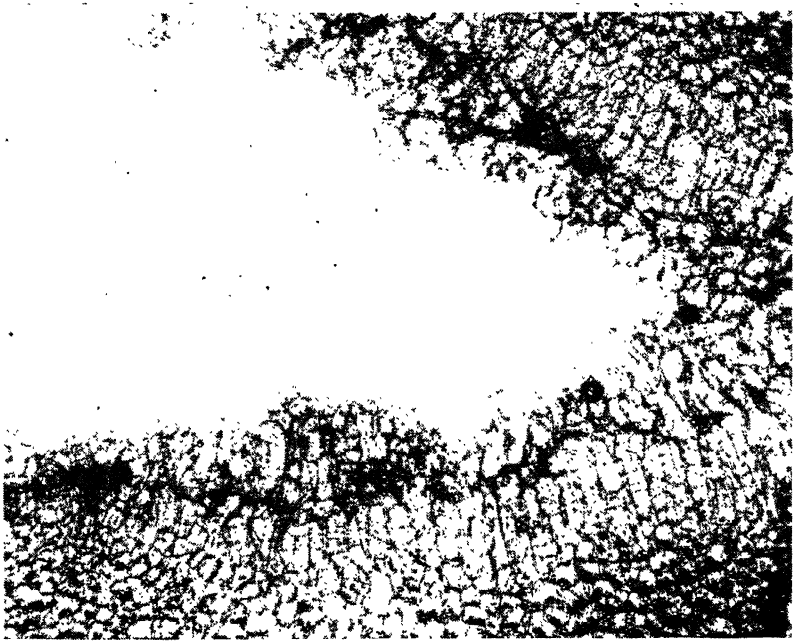

FIG. 6. Hollow about 6 x 16 mms. Tuber weight, 210 gms. 28x.

spherical, or flask-shaped (the neck of the flask being imbedded in the surrounding cells). In some cases, a large mass of small, thin, hyphal-like cells protruded into the cavity.

At least in the mature tubers, the middle lamella of the wound cambium was suberized, as judged by staining with Sudan III, yet the cells were still alive. All cells stated to be alive were judged on the basis of vital staining with neutral red, plasmolysis, and streaming movement.

Besides the 65 tubers showing hollow heart, a much larger number had necrotic areas, in the perimedulla or pith, consisting of patches of dead brown cells that resembled those initiating the hollow-heart condition. No cambium formation, however, was associated with these necrotic areas.

These observations reveal that the hollow heart cavity is not lysigenous in origin, since no cell disintegration or absorption occurs. On the other hand, it is not the simple type of schizogenous cavity which arises by separation of living cells at the middle lamella, resulting in a giant intercellular space. Its formation is preceded by the death of a patch of cells and the development of a wound cambium around them.

The correlation between tuber size and size of hollow agrees with the assumption that the formation of the hollow is a growth phenomenon. Exceptions are easily understood, since the necrotic patch was found to arise in tubers from 2 to 100 gms. in weight. The split presumably is due to continued expansion of the tuber after the dead cells in the necrotic region are no longer capable of enlarging. Only such a relation could permit the development of a wound cambium several cells thick around the necrotic zone before any split has occurred.

If the hollow is caused by the normal growth of the tuber following the death of a patch of pith cells, it should be possible to calculate the ultimate size of the hollow from the original size of the necrotic region. Should the calculated value correspond with the experimentally determined, this would be good evidence for the theory.

The known facts are as follows: the necrotic region was ½ mm. in its longest diameter (Fig. 1). The largest mature tuber weighed about 300 gms.; the smallest tuber in which the necrotic region was found weighed 2 gms. When mature, the hollows were lenticular-shaped, with their long axes in the short axis of the tuber. The dimensions were 10 x 20 mms. or greater.

It is a well-known physical law that when a hollow body expands uniformly, the hollow increases in volume proportionately to the body as a whole. Consequently, if we assume that the tuber volumes are

proportional to their weights (some volume measurements were made and found to agree with this) and the tuber shape is spherical, the final hollow should have a volume of $300/2 \times 4/3\ \pi r^3 = 300/2 \times 1/64\ (4/3\pi) = 4/3\pi \times 2.2$ mm.^{3} (app.). The volume of the mature hollow from measurement was actually $4/3\pi \times 500$ mm.^{3} (using the formula for an oblate spheroid) or 230x the calculated volume.

On the other hand, the volume of the necrotic region necessary to account for the observed size of hollow would be $4/3\pi\ (2/300 \times 500)$. This would mean a diameter of about 3 mm. in a 2 gm. tuber, which is six times the diameter of the observed necrotic regions. Since there is no direct evidence of the size of the necrotic region that gave rise to the mature hollow, we are forced to turn to such indirect evidence. It should be emphasized that the difference between the estimated and the experimentally determined values is really greater than the above figures indicate, because (1) hollows larger than 10x20 mms. were found, whereas the smallest tuber found with a necrotic region was used for the calculations, (2) the volume of the dead cells and the much larger volume of the wound cambium and callous cells were ignored.

Quantitatively, then, a uniform tuber growth outside of the dead cells cannot account for the ultimate size of the hollow. Qualitatively, it cannot account for its shape, for this would have to conform with the shape of the tuber.

Both the size and shape of the hollow can, however, be explained by a non-uniform growth of the tuber outside the necrotic region, such that the peripheral regions enlarge more rapidly than the central (the reverse relation would prevent the formation of a hollow). Direct evidence of this was obtained by cell measurements on some hollow heart Russets. Since the growth of the tuber is primarily due to cell enlargement (especially after the first symptoms of hollow heart arise), a measurement of cell size in the different tissues of the mature tuber should yield information as to the relative rates of growth that these regions have undergone.

Measurements were made on tissue adjacent to one face of the lens-shaped hollow (*i. e.* in the pith) and on tissue adjacent to one edge of the hollow (in the perimedulla). The sections were mounted in water after staining with neutral red. Only stained (*i. e.* living) and therefore turgid cells were measured. Each cell was measured along its longest and shortest axes and the two values were averaged.

These results agree with the conclusion that the perimedulla grows more rapidly than the pith during the formation of the hollow.

The cause of the death of the pith cells can only be conjectured. It

TABLE 2.—*Cell diameter of hollow-heart Russets. Each value is an average of* 100 *cells. Magnification* 125x.

TUBER	FACE OF HOLLOW	EDGE OF HOLLOW
1	19.0	23.8
2	18.8	23.0
3	18.9	23.4
Av.	18.9	23.1

cannot be lack of O_2, (oxygen) since rapid development of a cambium layer follows. Another possible explanation is a deficiency of some element. MacArthur (1940) describes localized or diffuse necrotic areas in apples suffering from boron deficiency. Starch was retained in these cells. A cork cambium partially or completely walled-off the lesion. There were also reactivated individual cells or groups of them. These three types resemble respectively the dead cells, cambium, and tylosis-like cells in the hollow-heart tubers.

In view of this resemblance, it was felt that a preliminary investigation of the mineral constituents might throw some light on the problem. Six hollow heart tubers (av.wt. 145 gms.) and a similar number of healthy controls (av.wt. 118 gms.) were chosen. Separate samples were taken from the pith and the perimedullary region of each tuber. These were dried, ashed, dissolved in H_2SO_4, and analyzed spectrographically (Nelson, 1942). The spectrograms were compared visually,

TABLE 3.—*Relative mineral contents of hollow heart and healthy tubers. Total of six tubers in each.*[1]

TISSUES COMPARED		K	Cu	Mg	Fe	Mn	Ca
EXCESS IN	OVER						
Healthy pith	Hollow heart pith	5	6	5	6	2	1
Healthy perimedulla	Hollow heart perimedulla	1	3	2	2	4	4
Healthy pith	Healthy perimedulla	12	10	12	13	11	13
Hollow heart pith	Hollow heart perimedulla	4	4	5	3	4	5

[1]The author wishes to express his gratitude to Dr. R. C. Nelson for instruction and aid in making the spectrograph determinations.

since only the relative amounts in healthy and affected tubers were required. The method adopted was to compare two spectrograms, *e. g.*, one from a hollow heart tuber with one from a healthy tuber, for each of the 6 elements investigated. Comparisons were made also between the pith and perimedulla of healthy tubers and the pith and perimedulla of affected tubers. The spectrogram showing the greater quantity of an element was characterized as 1, 2, or 3 units in excess. The results are given in table 3. Since too few analyses were made to justify statistical treatment of the results, the totals only are given. The individual results, however, agreed rather well with one another.

The hollow heart tubers appeared to have significantly less of all the elements investigated. This was slightly more pronounced in the pith than in the perimedulla. Furthermore, though the pith had a much higher concentration than the perimedulla, this difference was strikingly reduced in the hollow-heart tubers. There was no obvious difference among the six elements tested.

Summary

1. Hollow heart of potatoes was found to arise in a necrotic patch of cells after this had become surrounded by a cambium layer.

2. Though the largest hollows usually occurred in the largest tubers, early stages were found in tubers weighing as little as 1.8 gms.

3. The hollow heart condition was observed in the earliest harvest examined (July 24); the incidence in the first harvest was double that in the last; and treatments affected the incidence only when given early in the season. These three facts indicate that the disorder must have originated early in the season in all affected tubers.

4. Measurements revealed that the perimedulla cells adjacent to the edge of the hollow were larger than the pith cells adjacent to the face. This may indicate more rapid growth in the former tissue, a possible factor in hollow heart formation.

5. All six of the mineral elements investigated (K, Cu, Mg, Fe, Mn, Ca) occurred in higher quantities (on a dry weight basis) in the healthy than in the affected tubers. The excess in the pith compared with the perimedulla was also reduced.

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INCIDENCE OF HOLLOW HEART IN POTATOES AS INFLUENCED BY REMOVAL OF FOLIAGE AND SHADING[1]

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A high incidence of hollow heart observed in a field of Irish Cobblers that had been severely frosted at the time of tuber setting, with partial later recovery, suggested that hollow heart might be experimentally produced thereby facilitating the study of its causes and development.

In 1940 at the North Central branch station at Grand Rapids, Minnesota, potatoes were given five treatments consisting of the removal of 0, 20, 40, 60, and 80 per cent of the foliage. The effect of these treatments on the incidence of hollow heart when applied at three different periods of tuber development was studied on the Irish Cobbler variety, using 4 randomized blocks. In 1941 the above experiments were repeated with slight modifications. The 20 and 40 per cent removal of foliage treatments were replaced with two shading treatments in which the plants were shaded for 5 and 10 days respectively with black sateen cloth. The plants of all treatments were allowed to mature and were then harvested and examined for hollow heart. In 1941 a special group was harvested at successive periods of tuber development and then examined.

The incidence of hollow heart obtained after the removal of varying amounts of foliage at successive stages of development is presented in table 1. In 1940 a significant decrease in the number of hills free from hollow heart was obtained on the plants which had 60 and 80 per cent of their foliage removed on the 9th of July. Plants on which 20 and 40 per cent of the foliage was removed on this date showed a slight, but not significant decrease, in hills free from hollow heart. The results for 1941 were similar. The plants on which 50 and 75 per cent of the foliage was removed had fewer hills free from hollow heart. The increase in the number of hills showing hollow heart when most of the foliage was removed at the time of tuber setting and the absence of any effect of this treatment at later stages of growth, suggest that the initial breakdown resulting later in hollow heart tubers may have its inception in the early stages of tuber development.

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TABLE 1.—*Number of hills without hollow heart tubers under given amount of foliage removed at specified dates.*

Date of Treatment	Number of Hills Free from Hollow Heart in Indicated Classes[1] (1)					Total Number
1940	Percentage of Foliage Removed					
	0	20	40	60	80	
	Number	Number	Number	Number	Number	
July 9	17	15	15	13	11	71
24	17	18	15	19	13	82
August 10	17	19	17	18	19	90
TOTAL	51	52	47	50	43	243

Date of Treatment	Number of Hills Free from Hollow Heart in Indicated Classes[1] (1)						
1941	Percentage of Foliage Removed			Total	Shading		Total
	0	50	75		5 Days	10 Days	
	Number	Number	Number	Number	Number	Number	Number
July 8	14	8	6	28	19	19	38
29	14	15	20	49	15	16	31
TOTAL	28	23	26	77	34	35	69

[1]Total hills in each class—20.

The shading treatments were designed to determine if the initial breakdown was due to a temporary deficiency of synthates accentuated by the removal of foliage. It will be noted in table 1 that plants shaded for 5 and 10 days on July 8 significantly more hills free from hollow heart than those plants on which foliage was removed on that date. Later shading on July 29 had no appreciable effect on the incidence of hollow heart. The results obtained from shading indicate that a temporary lull in photosynthetic activity is not the initial cause of hollow heart. The reduced incidence of hollow heart obtained from the shading during the early stages of tuber development supplies additional evidence of the importance of this stage in the initial breakdown which results in hollow heart.

Further evidence that hollow heart had its initiation in the early period of tuber development is supplied by the incidence of hollow heart at successive periods of tuber development. The results for five successive harvests are given in table 2. Hollow heart tubers were found

TABLE 2.—*Incidence of hollow heart at successive periods of tuber development.*

Date	Days after Planting	Number of Hills	Weight per Hill	Weight per Tuber	Hills with Hollow Heart	Tubers with Hollow Heart	Mean Weight of Hollow Heart Tubers
	Days	Number	Grams	Grams	Per Cent	Number	Grams
July 23	60	21	157.0	7.48	23.8	7	45.5
August 6	70	25	399.8	15.10	32.0	11	59.4
20	83	24	627.2	26.30	20.8	7	84.9
Sept. 3	104	25	752.6	38.71	28.0	9	133.0
Sept. 10	111	25	776.1	53.01	24.0	8	105.7

in 23.8 per cent of the hills harvested 60 days after planting. At this time the average weight per hill was 157.0 grams and the weight per tuber was 7.48 grams. The hollow heart tubers averaged 45.5 grams. Thus at this stage as well as at later stages hollow heart was associated with the larger tubers. There was no significant increase in the percentage of hills with hollow heart tubers, nor in the number of tubers with hollow heart, in successive harvests. The smallest tubers examined weighed two grams and hollow heart was observed in one of these. The above observations would indicate that in this material hollow heart was initiated at, or very shortly after, tuber setting. Further studies of this period would be desirable to determine more accurately at what point inception is most likely to occur, and whether the initiation of hollow heart is confined to this early period of tuber development.

The increase in the incidence of hollow heart by removal of foliage at the time of tuber setting was accompanied neither by a significant decrease in number of tubers and yield per hill nor in average weight per tuber. The results are presented in table 3. The removal of 20, 40, 60, and 80 per cent of the foliage on the 9th and 24th of July, and on August 10 was followed in each case by a vigorous renewal of new growth which ultimately resulted in total growth equal to that of the non-pruned plants. This renewal of growth was associated with delayed maturity which in some cases amounted to as much as two weeks. A similar response in growth of foliage was obtained in 1941. But before maturity the vines were destroyed by late blight. Under these conditions the plants with foliage removed produced a significantly lower yield than those plants which were allowed to retain their original

TABLE 3.—*Influence of removal of foliage on number and yield of potatoes per hill, and weight of individual tubers.*

Date of Treatment	Mean Number of Tubers per Hill in Indicated Classes				
	Percentage of Foliage Removed				
	0	20	40	60	80
	Number	Number	Number	Number	Number
July 9	11.05	8.35	8.65	10.15	9.80
24	8.60	9.15	7.65	9.35	9.35
August 10	8.85	8.20	8.50	8.45	10.30
Mean	9.50	8.57	8.27	9.32	9.82
	Mean Weight of Individual Tubers in Indicated Classes				
	Pounds	Pounds	Pounds	Pounds	Pounds
July 9	2.41	2.21	2.05	2.20	2.23
24	2.03	2.20	1.89	2.25	1.76
August 10	2.16	2.23	1.83	2.11	2.18
Mean	2.20	2.21	1.92	2.19	2.06
	Mean Weight of Individual Tubers in Indicated Classes				
	Pounds	Pounds	Pounds	Pounds	Pounds
July 9	.218	.265	.237	.217	.228
24	.236	.240	.247	.241	.188
August 10	.244	.272	.215	.250	.212
Mean	.233	.259	.233	.236	.209

foliage. A comparison of hills with and without hollow heart irrespective of treatment showed that hollow heart tended to be more prevalent in the heavier yielding hills. Furthermore at maturity it was found that hollow heart was almost entirely confined to the largest tubers in the hill.

DISCUSSION

The incidence of hollow heart was increased by removal of foliage and decreased by shading when applied at time of tuber setting but not when applied at later periods of development. The incidence of hollow heart was not significantly different in plants harvested at successive periods of tuber development. These results indicate that the breakdown ultimately resulting in hollow heart had its inception during the initial development of tubers or shortly thereafter. Moore (3) working

with the Russet Rural variety did not observe any hollow heart in 46 hills examined 72 days after planting when the average weight of tubers was 3.6 ounces. He found at the end of 82 days, 3.56 per cent; at 100 days, 5.78; and after the vines were killed by frost at 108 days, 10.86 per cent of tubers affected with hollow heart. On the basis of this information it was expected that the removal of foliage and shading would exert its influence on the incidence of hollow heart, if any, when applied during the later rather than as found during the earlier period of tuber development. In a histological study of the development of hollow heart, Levitt (1) found that hollow heart was initiated as a necrotic patch. Although some association between size of the cavity and the size of the tuber was evident, nevertheless stages 1, 2, and 3 were observed in tubers of approximately the same size. The occasional presence of necrotic patches in medium-sized tubers may indicate that the inception of hollow heart is not entirely confined to the early growth of the tuber. In this connection the absence of stage 1 in the largest tubers is probably significant. The relatively large cavities in the heavier tubers seem to have been initiated when the tubers were small as Levitt observed that the development of hollow heart is a gradual process more or less concurrent with the growth of the tuber.

The plants with foliage removed at successive stages of growth did not significantly differ from untreated plants in mean number of tubers and yield per plant and in the weight of individual tubers, although in all treatments hollow heart was associated with the higher yielding hills, and with the larger tubers in the hill. The latter is in harmony with previous observations of Moore (2, 3) and Werner (4,5). Furthermore these investigators have generally associated hollow heart with periods of rapid vegetative growth. In the experiments reported in this paper, the removal of foliage did initiate a period of rapid vegetative growth. This rapid vegetative growth was found to be associated with an increase in the incidence of hollow heart at the early but not at the later stages of tuber development. This association and the necrotic areas observed by Levitt which precede the formation of a cavity suggest that a temporary nutritional deficiency in the tuber may be the initial cause of the disintegration of the tissues.

Summary

The removal of foliage at successive stages of tuber development in 1940 and 1941 caused a decrease in the number of hills free from hollow heart when applied at the time of tuber setting but not at later periods.

Shading the plants with black sateen cloth for intervals of 5 and 10 days tended to increase the number of hills free from hollow heart when applied at time of tuber setting but had no effect when applied 21 days later.

Approximately the same incidence of hollow heart was observed in hills harvested when their average weight was 157 grams and the average tuber weight was 7.5 grams, as when the plants matured and the average weight per hill was 776 grams and the average tuber weight 53 grams.

The removal of 20, 40, 60, and 80 per cent of the foliage did not significantly influence the average number of tubers set per hill, the mean yield per hill, nor the mean weight of the individual tubers.

The removal of foliage was followed by a very active renewal of vine growth and a delayed maturity of the vine. This active renewal of vine growth may have been a significant contributing factor in increasing the incidence of hollow heart in the early period of tuber enlargement.

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NEW DEVELOPMENTS ON CERTIFYING SEED POTATOES

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Each season gives us new experiences and knowledge concerning potato certification. Not a year passes without some new problem that has to be met. Since these problems are usually related to the appearance or desirability of certified seed stocks, they are not always disease factors.

Ring rot is a disease, however, which has multiplied the problems of certification, especially if an absolute zero tolerance is to be maintained.

A few seasons ago, two field inspections were considered sufficient.

Now, because of Ring rot, additional precautions are necessary. This often results in several field inspections and greatly increased costs to be absorbed by the inspection service and, in turn, by the certified seed growers.

Although all certified growers are now using extreme caution to avoid contamination with the organism, occasionally it is not accomplished. We inspected 37,000 acres for certification this past season and found one or more infected plants in approximately 5,000 acres. We suspected its presence in some instances because of the general knowledge and history of the grower or seed stock. In several cases it was not suspected. Usually, of course, a thorough check-up will reveal the possible source of contamination.

It has increased the hazard of certification several fold. Imagine yourself, for example, planting 200 acres with supposedly healthy seed. You apply for certification, pay an application fee amounting to $170.00. You rogue the field diligently all summer, which may cost you more than $200.00. Until that time, you have reason to expect a fine, practically virus-free crop, eligible for certification. But just before maturity, an inspector, after several inspections, finds three or four plants affected with Ring rot and can find absolutely no more, even after hours of searching. Nevertheless, your field is rejected. You can visualize the hazard and disappointment caused by such circumstances. In most instances such as this, there is no evidence of the disease to be found on or within the tubers at harvest.

How would this stock have performed had it moved out as certified? Frankly, we think it would have performed wonderfully well. In fact, similar seed has done so. It could easily be superior to other stocks in performance because of various factors.

As you know, some receiving states demand an absolute zero tolerance and reject and condemn shipments when one infected tuber is found. Some of these same shipments have been diverted elsewhere and have given very pleasing results. Personally, I do not blame a receiving state or individual for being concerned about the slightest sign of Ring rot in a shipment—especially if there is any question regarding how late the inspection was made, how thorough the field inspections were, the history of the stock, how contamination occurred, etc. We feel that when we have an opportunity to make good, timely inspections, we can

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[1]North Dakota Seed Commissioner.

[2]Paper presented at A. A. A. S. Meetings, at Dallas, Texas, Dec. 30, 1941.

tell the seed's desirability and will bank our reputation on the same. We prefer our receivers to place such confidence in us.

In an occasional case there is a chance that ideal inspections cannot be made and a trace of the disease not discovered. When such an error is apparent, we are glad to know about it and correct it, so that it will not happen with the same stock again.

Frankly, we have had 6 or 8 car rejections in the south because of Ring rot. In these instances, we were apparently the last to hear about it. With 100 per cent cooperation between officials, it would seem that we should have been the first to get direct information, in order to prevent further shipments of such stock immediately. For this reason, better knowledge, cooperation, and understanding between the officials should be developed.

Another point which receiving states should consider is the hazard placed in shipment of stocks over long distances. For example, if you were a dealer in certified seed and purchased and paid for a fine car of seed, but encountered an official rejection or condemnation at destination—one which was beyond your control—and, which you considered technical and somewhat unwarranted, you might be fearful, and even avoid future shipment into such a state. With many such instances, growers within said receiving state might be confronted with a higher quotation to take care of the added rejection hazard. In other words, a practical solution should always try to be consummated.

Only recently I talked with a very prominent grower who had a large quantity of very outstanding seed. Only one plant of mild mosaic was found in his acreage before roguing. He harvested his crop under ideal conditions and the stock was apparently very good. So I suggested the shipment of some of this stock to a definite area in a certain state where I thought it would greatly increase North Dakota business another season. He said, "Nothing doing," because of experiences a year ago. When seed is plentiful, no noticeable harm may be done. But in short-crop years a hardship may affect the growers of that state.

North Dakota will, of course, do its best to maintain a zero tolerance in its seed stocks if the trade continues to insist upon it. If the trade is willing to take our judgment regarding the desirability of seed, we think they will still get very dependable seed. We fully realize when stocks are used for a second seed crop that an absolute zero tolerance is essential.

In summarizing, we feel that dependence of seed quality should be placed almost entirely with the agencies or states actually doing the work and that too technical an attitude by receivers or officials in the

receiving states may not mean the greatest returns to their growers. We say this, having in mind a zero, so near a zero tolerance for Ring rot, that no harmful effects could possibly result.

We hope to learn more concerning this problem during the season of 1942, and if indications show that future dependability and business necessitate an absolute zero, we will no doubt maintain it even though receiving states do become slightly more lenient on their requirements.

Several hundred acres are planted in the south with the stocks we rejected, because of the presence of traces of Ring rot. We hope to observe these fields very carefully throughout the season.

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NEWER POTATO VARIETIES CAN BE PRODUCED WITH LESS LABOR AND EXPENSE THAN SOME OF THE OLD

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The potato grower is confronted at present with a situation that calls for efficiency in every detail of his work. Labor is scarce and high-priced, and seed and fertilizers cost more money than usual. In fact, nitrogenous fertilizers may be increasingly difficult to obtain regardless of price. Chemicals for seed treatment and copper sprays are also becoming more difficult to obtain, and should be used as sparingly as possible. If the grower is to increase production without decreasing the quality of his product he will have to make his labor count for more.

Some of the standard varieties are hard to excel for yielding ability and quality if they can be grown free from disease and insect injury. In many cases this seems almost impossible, however, and large losses occur, sometimes because of neglect on the part of the grower, but often after the grower has followed the best known recommendations of culture and disease control.

Within recent years 5 early varieties (Earlaine, Mesaba, Nittany Cobbler, Red Warba, and Warba) and 9 late varieties (Katahdin, Chippewa, Houma, Earlaine 2, Golden, Pennigan, Pontiac, Sebago, and Sequoia) have been made available to growers. Because of resistance to various diseases and insects some of these produce satisfactory crops

[1]Senior Geneticist.
[2]Assistant Plant Breeder.

TABLE 1.—*Certified seed of new and standard varieties*[1] *grown in the United States in* 1941.

State	Irish Cobbler	Triumph	Green Mountain	Katahdin	White Rose	Russet Burbank	Chippewa	Russet Rural	Early Ohio	Rural New Yorker	Burbank	Other Varieties[2]	Production by States	Percentage of Totals by States
	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	
Calif.	.....	.....	.....	.....	22.7	28.0	.....	.....	.....	.....	7.9	.....	58.6	0.3
Colo.	88.5	69.7	.....	85.7	15.6	9.2	6.0	3.3	.....	21.9	.....	157.2	457.1	2.6
Idaho	1.5	23.7	.....	.8	.....	335.9	.2	.....	.....	.....	.....	5.8	367.9	2.1
Maine	2,370.7	90.3	2,347.3	1,664.8	.....	.....	441.0	53.3	0.5	.....	.....	724.9	7,692.8	43.7
Md.	7.7	.....	.....	.....	.....	.....	.....	0.3	.....	0.2	.....	10.0	18.2	.1
Mich.	9.3	1.9	13.1	19.9	.....	.....	48.2	223.7	.....	1.3	.....	6.8	324.2	1.8
Minn.	1,021.9	660.6	16.9	49.3	58.5	45.4	57.2	1.2	170.5	4.1	0.4	97.0	2,183.0	12.4
Mont.	.1	91.7	.....	.....	65.3	62.3	.....	.....	.....	.....	.....	2.1	221.5	1.3
Nebr.	9.2	1,049.1	.....	6.4	.....	.....	0.7	.....	.....	.....	.....	1.2	1,066.6	6.1
N. H.	.1	.....	44.9	.....	.....	.....	.....	.....	.....	.....	.....	1.4	46.4	0.3
N. J.	12.5	.....	1.0	22.3	.....	.....	20.2	.....	.....	.....	.....	4.1	60.1	0.3
N. Y.	35.8	9.2	225.3	188.0	.....	.....	42.2	13.8	.....	28.3	.....	54.6	597.2	3.4
N. C.	.....	.....	.8	.....	.....	.....	.....	.....	.....	.....	.....	11.1	11.9	.1
N. Dak.	900.0	1,200.0	.....	4.5	28.0	0.6	16.0	.....	110.0	.....	.....	23.1	2,282.2	13.0
Oreg.	1.3	1.5	.....	1.5	260.0	216.6	.....	.....	.....	.....	70.8	10.0	561.7	3.2
Pa.	.....	.....	.2	38.2	.....	.....	13.4	122.5	.....	39.4	.....	28.0	241.7	1.4
S. Dak.	34.5	228.3	.....	.....	1.6	.....	1.5	.....	8.5	.....	1.8	0.1	276.3	1.6
Tenn.	2.2	42.1	6.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	51.0	0.3
Utah	5.3	28.8	.....	.....	1.6	20.7	.....	.....	1.2	.....	.....	.....	57.6	0.3

[1]The data in table 1 were compiled from the summaries of the Agricultural Marketing Service, U. S. Department of Agriculture, Washington, D. C., and from lists of certified potatoes from the different State Departments of Agriculture.

[2]Other varieties include: Mesaba, 5,490 bushels; Nittany Cobbler, 7,140; Red Warba, 55,126; Warba, 44,496; Houma, 272,523; Earlaine, 2, 26,547; Pennigan, 3,748; Pontiac, 13,025; Sebago, 479,428; Sequoia, 21,117; Peachblow, 17,900; Brown Beauty, 8,535; Charles Downing (Idaho Rural), 5,800; Early Rose, 3,500; Dakota Red (Jersey Redskin), 3,327; Red McClure, 131, 625; Spaulding Rose, 10,358; Unclassified, 25,373.

of potatoes with less labor and less spray materials than the standard varieties. Some of them, such as the Katahdin, are widely adapted; others are perhaps more limited in their range of adaptation. Two of them, Earlaine and Golden, have not made a place for themselves and seem to be on their way out of production. Others are being increased very rapidly if the relative amount of certified seed of each grown in 1941 is taken as a criterion. A summary of the certified seed produced in the United States in 1941 is given in table 1. None of the new early varieties has entered into serious competition with the Irish Cobbler and the Triumph.

Earlaine produces a smoother tuber than Irish Cobbler and is immune in the field to mild mosaic, but so is the Irish Cobbler. In the Maine tests the two yield about the same, but in tests in other parts of the country where conditions are less favorable for potato production Earlaine is not so dependable as the Irish Cobbler. As a result Earlaine is not being increased. Mesaba is another early variety that does not seem to be widely adapted. The type of its tuber is excellent, and under favorable growing conditions large tubers are produced in a very short time, but it does not compare favorably with Irish Cobbler when grown under adverse conditions. Between 5,000 and 6,000 bushels of certified seed of Mesaba were grown in 1941, most of it in Minnesota (table 1, footnote). Nittany Cobbler is very much like Irish Cobbler in its growth habits and production. In fact, most people cannot see any difference between them. About 7,000 bushels of seed of this variety were certified in Pennsylvania in 1941.

The reports indicate that Red Warba and Warba are on the increase. About 55,000 bushels of Red Warba and 44,000 bushels of Warba were certified in 1941, the greater part in Minnesota. These two varieties are quite alike except for color. The Red Warba, a sport of the Warba, produces red tubers with splashes of white; the Warba, white tubers with pink eyes. Both of these have been discriminated against to a certain degree because of their tuber color, but they are both very early and usually give high yields.

Though it is true that the new varieties of early potatoes have not competed seriously with the Irish Cobbler and the Triumph, the picture among the late varieties is quite different. Katahdin was the first new variety to be distributed under the national potato breeding program, consequently is the most widely known. It has had a phenomenal increase in production. This is due for the most part to its disease resistance and to its wide adaptation. In 1932 only a few acres of this variety were grown, and in 1941, 2,103,901 bushels of certified seed

TABLE 1.—*Certified seed of new and standard varieties*[1] *grown in the United States in* 1941 (Continued)

State	Irish Cobbler	Triumph	Green Mountain	Katahdin	White Rose	Russet Burbank	Chippewa	Russet Rural	Early Ohio	Rural New Yorker	Burbank	Other Varieties[2]	Production by States	Percentage of Totals by States
	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels	
Vt.	.....	.....	97.2	5.9	.....	.....	.....	.....	.....	.....	.....	5.0	108.1	0.6
Wash.	1.0	2.0	.....	.....	372.7	62.8	.....	.....	.....	.....	1.2	0.3	440.0	2.5
Wis.	37.8	31.3	16.1	13.6	2.5	0.4	52.8	9.7	.....	10.3	.....	2.3	176.8	1.0
Wyo.	5.3	265.0	.....	2.9	.....	.....	.....	1.6	.....	.....	.....	.....	274.8	1.6
Other States	2.1	7.6	.....	0.1	.....	.....	.....	.....	. ...		.....	0.1	9.9	.1
Total production for varieties	4,546.8	3,802.8	2,769.5	2,103.9	828.5	781.9	699.4	429.4	290.7	105.5	82.1	1,145.1	17,585.6	
Total percentage for varieties	25.9	21.6	15.7	12.0	4.7	4.4	4.0	2 4	1.7	0.6	0.5	6.5		

were produced. This is 12.0 per cent of all the certified seed grown in the United States in that year. Among the late varieties it was exceeded only by Green Mountain with 15.7 per cent of the total production. Katahdin has been grown successfully in many of the late-producing states and in certain of the southern sections such as in the Hastings District of Florida. It has been produced rather extensively in Argentina and Uruguay, and a recent report from Australia stated that it was revolutionizing potato growing in the western part of that country. It produces relatively high yields over a wide range of environmental conditions. Its tubers are usually well-shaped with shallow eyes, and therefore they are much easier to wash or brush in preparation for the market than the tubers of some of the old commercial types.

Katahdin tubers have been criticised for their cooking quality, they are not so mealy as those of the Green Mountain grown in Maine or part of New York State, to which the latter variety is especially adapted. In the 1941 cooking tests conduted in cooperation with the Bureau of Home Economics the rating of Katahdin, grown on the Aroostook Farm, Presque Isle, Maine, averaged 4.13 as compared with 4.53 for Green Mountain. The highest possible rating was 5.00. The Katahdin, as usual, was not so mealy as the Green Mountain, but the flesh of the former did not turn black after cooking to such a degree as did that of the latter. Another character that affects the cooking quality of the tubers is the net necrosis too frequently found in the tuber flesh of the Green Mountain, because of current-season infection with leaf roll. In recent years the spread of leaf roll with its accompanying net necrosis has been a serious problem in the production of Green Mountain potatoes in parts of Maine. Katahdin does not contract leaf roll so rapidly as Green Mountain, and when it becomes infected with leaf roll virus it apparently does not develop net necrosis in the flesh of the tubers. If net necrosis had been taken into consideration in judging quality of the Green Mountain, a part of the samples would have to be scored unfit for food. The freedom of Katahdin from net necrosis is perhaps the chief reason it is increasing in Maine, and in some sections replacing the Green Mountain for table stock production.

Katahdin is commercially resistant to mild mosaic, a disease that causes much of the "running out" in the Green Mountain. This is a distinct advantage, especially to the grower of certified seed, since it requires less labor to keep Katahdin within the certification limits. It will be advantageous also to sections such as Louisiana where the growers depend on getting seed every year from northern or western states. If boats and other facilities of transportation become limited in the war

emergency the growers in many sections may be compelled to save their own seed, in which case the Katahdin will not "run out" so quickly as the old standard varieties. Under such circumstances it will be necessary to provide better storage facilities than are generally available in southern sections. Katahdin is somewhat resistant to southern bacterial wilt, and this gives it an advantage over the Spaulding Rose, which it has replaced largely in the Hastings District of Florida.

Chippewa was released a year later than Katahdin. It is not so widely adapted as the latter variety, and has not increased so rapidly in production. Nearly 700,000 bushels of certified seed of Chippewa were grown in 1941. Nearly two thirds of this amount was produced in Maine, but certain amounts were grown also in Michigan, Minnesota, New Jersey, New York, North Dakota, Pennsylvania, and Wisconsin. Chippewa, like all other varieties of potatoes, has some good and some poor qualities. Like Katahdin it is immune to mild mosaic, in the field. It is about as susceptible to leaf roll as Green Mountain, but so far no net necrosis has been reported in its tubers as the result of leaf roll infection. It produces high yields, especially on muck soils, of smooth shallow-eye tubers that can be washed or brushed much more effectively than deep-eye varieties, such as the Irish Cobbler. The cooking quality of Chippewa is quite variable. In Maine, New York, and New Jersey its quality ranges from poor to good. In Michigan it sets the standard for quality, as its tubers do not have the tendency to turn dark after cooking to such a degree as those of the Rurals or Green Mountains. The quality of Chippewa grown in Wisconsin and Indiana is quite satisfactory, and the tubers usually bring a premium on the markets. The worst feature of Chippewa is the tendency of its leaves to roll when conditions are not favorable. This rolling, sometimes referred to as non-virus leaf roll, is very difficult at certain stages of plant development to distinguish from the true leaf roll resulting from virus infection. The efficient grower who rogues his fields at the right time, just as soon as any disease can be detected, finds no difficulty in producing certified seed, but the grower who delays roguing until it is too late to rogue any variety will have difficulty in distinguishing between the non-virus and the virus leaf roll in Chippewa.

Houma is another new variety that is increasing in production. It produces satisfactory yields in Maine. The cooking quality of its tubers is usually quite good, though rarely as high as that of Green Mountain. Its big advantage over the latter variety is its resistance to mild mosaic and to the net necrosis resulting from leaf roll virus infection. The 1941 certified lists show 272,523 bushels of Houma

seed, with the largest amount in Maine, as shown in table 1.

Earlaine 2 has increased in production in Aroostook County and is spreading to other states. In 1941, certified seed production reached 26,547 bushels. Its ability to produce high yields is its main recommendation. It has had very poor cooking quality in all tests. In 1941 it ranked highest in yield and lowest in cooking quality, among the 16 varieties grown on Aroostook Farm, Maine.

The history of Earlaine 2 is as follows: A grower, visiting the breeding plots of the Bureau of Plant Industry at Aroostook Farm put a few tubers of one of the seedlings in his pocket. When the Earlaine was distributed it was believed that the tubers he had taken were Earlaine, and they were grown under that name for a year or two. Later, comparisons of the two varieties by the federal investigators showed that they differed, the Earlaine being earlier in maturity and a lighter producer. Subsequently the variety picked up by the grower has been called Earlaine No. 2. This is unfortunate as it leads to confusion. In fact, Earlaine No. 2 is too poor in quality to warrant its being retained as a variety. If it were the purpose of this article to make recommendations one would be that Earlaine 2 be dropped from all lists of certified varieties.

There is a limited demand for yellow-fleshed varieties, especially from South American countries that were formerly accustomed to buy such varieties from Europe. Golden, the only yellow-fleshed new variety is no longer grown as a commercial crop. Its yield and quality when grown under favorable conditions were quite satisfactory, but it had a short rest period and, consequently, poor keeping quality when marketed. It kept well in storage, such as is available at the Aroostook Farm, but when it was marketed in the usual way it began to sprout and thus to lose its marketable qualities before it could be sold.

Pennigan resembles Rural New Yorker No. 2 to a high degree. It should be adapted to sections in which the Rurals can be successfully grown. The Pennsylvania seed lists show that 3,748 bushels of this variety were certified in that state in 1941.

The Pontiac is a late red variety. It usually produces high yields, especially on muck soils. In 1941 trials at the Aroostook Farm it was in the same class in yield but did not rank so high in cooking quality as the Green Mountain. It has not shown any marked resistance to insect pests and disease attacks; neither has it been much more susceptible than the old standard varieties. In some trials in Michigan and Iowa it has proved to be more drought-resistant than other varieties and has been freer from hollow heart and misshapen tubers.

Sebago is a late high-yielding variety that has had a rather remarkable increase in production in the Northern States. It was named and distributed in 1938, and 479,428 bushels of seed were certified in 1941. It has a number of characters that should recommend it under the present conditions in districts where late varieties are produced. It is highly resistant to mild mosaic and requires less labor to rogue. It is susceptible to leaf roll, but in-so-far as is known at present it does not develop net necrosis in the tubers as a result of infection with the leaf roll virus, a condition that resulted recently in large losses to growers of the Green Mountain variety. Its vines are moderately resistant to late blight, and its tubers to the rot initiated by the late blight fungus. In limited tests in 1937, a year when the blight epidemic was light, Sebago yielded as much in non-sprayed plots as it did where it was sprayed. In 1938, however, under severe epidemic conditions, the non-sprayed plot was reduced in yield but the difference between Sebago non-sprayed (339 bushels per acre) and the Green Mountain sprayed (383 bushels per acre) was statistically barely significant. The Green Mountain non-sprayed yielded 221 bushels per acre. It should be understood here, however, that Sebago is not resistant to leaf hoppers, and if it is to be grown in sections where these insects are a serious menace it should be sprayed to prevent hopperburn. In the yield tests at Aroostook Farm, where the plots of both varieties were carefully sprayed, the Sebago yielded 332 bushels per acre for a 6-year average; the Green Mountain 373.

The cooking quality of Sebago is rarely as high as the Green Mountain, and seems more variable. In 1940 Sebago was only slightly mealy; Green Mountain was very mealy. In 1941 the difference between them in cooking quality was barely significant. If Sebago is planted early and grown to maturity the quality is good, but like every other variety if it is harvested in an immature state the tubers will be more or less soggy.

Sequoia, selected in North Carolina from a cross between Green Mountain and Katahdin, is the newest member of the group. It continues to be an outstanding variety in yield in western North Carolina and western Maryland. It also produces high yields in some of the northern states. In the Maine tests in 1941 the difference between the yields of Sequoia and Green Mountain was not statistically significant. Sequoia ranked between average and good in quality, which was somewhat lower than Green Mountain. Its tubers sometimes grow too large, in which case they have a tendency to be rough. This can be overcome by closer planting or by using less fertilizer. The latter pro-

cedure might be a big advantage in a time when fertilizer is scarce and high-priced. One of the growers in western North Carolina is using just one-half the fertilizer on Sequoia that he does on Green Mountain and is producing comparable yields. Sequoia can be grown more cheaply than Green Mountain for other reasons. The former is not so susceptible to mild mosaic as the latter; its vines are somewhat resistant to late blight, and it is tolerant to leafhoppers and flea beetles. Spraying is beneficial to Sequoia, but it will produce a satisfactory crop without spray or with fewer applications than the standard varieties require. This might mean the difference between raising a good crop or a very poor one in times like these when the supply of Bordeaux mixture is uncertain.

NEBRASKA SEED IMPROVEMENT PROGRAM FOR NEBRASKA POTATOES

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Nebr. Certified Potato Grower's Coop.
Alliance, Nebr.

The Certification Department of the Nebraska Certified Potato Growers Cooperative assumes the responsibility for developing and maintaining superior, practically disease-free seed for the Nebraska potato grower. Superior seed is produced by the use of a seed improvement program, which involves tuber-indexing, tuber-unit planting in the field, and field roguing by trained men. The chief step in the seed improvement program is indexing. By this process, all diseased and undesirable tubers or hills are eliminated. The virus diseases, Spindle Tuber and Mosaic, are removed principally.

Indexing assures a practically disease-free lot of potatoes. The indexed potatoes are planted in well isolated fields, rogued carefully, and eventually released to a grower. The grower may then be certain of a high quality seed stock with which to plant his certified acreage

HISTORY

Seed stock improvement began in Nebraska, in the year 1923. Dr. H. O. Werner, of the College of Agriculture, at Lincoln, Nebraska,

indexed several thousand tubers prior to planting in western Nebraska, and each season continued the indexing work until 1934. During this time, he developed the clonal or tuber line system. Clonal lines improved the Triumph Variety by introducing even maturity within each lot of potatoes.

In 1934 and 1935, a small amount of experimental indexing was conducted by the Certification Department of the Nebraska Certified Potato Growers, the agency conducting seed certification in Nebraska. In 1936, the entire program was taken over, and has since been conducted by that organization.

The acreage devoted to increase of indexed tubers is known as Seed Farms. Seed Farm acreage in western Nebraska has increased gradually since 1924. From five to fifteen acres were maintained annually until 1931. In 1931, fifteen acres were planted at the Box Butte Experiment Farm, and increased to twenty-five acres by 1934. In 1939, a peak acreage of 150 acres was planted. Approximately 125 acres have been planted each year since that time.

Selection of Stock

Clonal lines, which have been propagated annually since their introduction from indexed tubers, serve as the source of seed to be indexed. Prior to harvesting, individual units are selected on the basis of vine type, disease freedom, and uniform maturity of line. The selected units are staked until time of digging.

Preparation and Indexing

Two methods of indexing are followed. One is the indexing of individual tubers under controlled conditions in the greenhouse, the other is the indexing of separate hills of potatoes in a southern state.

Greenhouse indexing of individual tubers begins with the selection of tubers from the uniform strains (clonal line) of Seed Farm Stock. In late fall, these tubers are taken to a workroom, which is completely disinfected between strains with HTH solution, as a protection against Ring Rot contamination. Here the tubers are numbered with a rubber stamp, using water-proof ink. A numbered seed piece containing an eye is removed, suberized under warm, humid conditions for about 100 hours. (Temperature of 70° F., humidity of 75 per cent). After suberization, all the seed pieces are treated with ethylene chlorhydrin to break the rest period (discontinued late in winter).

The seed pieces are then planted in an electrically heated, germinating bench. This bench is filled with peat moss and is kept at 70° F. As soon as the seed pieces have sprouts varying from one to two inches in length, they are transplanted into soil benches. An air temperature of 65° to 70° F. is then maintained in the greenhouse.

The tubers from which the seed pieces have been removed are suberized under the same conditions as were given the seed pieces. After they have suberized, the tubers are placed in cold storage at approximately 38° F.

When the greenhouse plants are six to eight inches high, the first reading is made. Another reading is made in seven to ten days. Any diseased or weak plants are removed, and their numbers recorded. As soon as these readings are obtained, all tubers having numbers corresponding to the seed pieces showing disease, are removed and destroyed. The disease-free tubers are then grouped together according to strain or variety.

Preparation for southern indexing of hills of potatoes is begun by marking one-pound and ten-pound paper sacks with corresponding numbers. These sacks are then taken to the field where plants have already been selected for digging. A hill is dug, making certain that all tubers from the hill are grouped together. Two small tubers about 1½ ounces in weight are taken from the hill and placed in the one-pound sack. The balance of the hill is placed in the large paper sack having the number corresponding to the small sack. The small paper sacks, with their contents, are then placed in numerical order, and held for shipment to Alabama in January. The large sacks, with the balance of the tubers from the hills dug, are placed in cold storage, where they are held until disease readings are available.

When the planting is conducted in the south, great care is taken to plant the tubers in their correct numerical order, so that their identity may be known at all times. Readings on this plot are recorded about the middle of April. At this time, all diseased, weak, or otherwise undesirable plants are recorded, and the information taken back to Nebraska. With this information, the numbered hills in cold storage are checked. Hills which are diseased, as shown by the southern readings, are discarded. The disease-free hills are then grouped according to strain or variety.

Planting—Roguing—Harvesting

In the spring, the disease-free strains or varieties of potatoes are

planted in the field by the tuber unit method. These fields are well isolated from any other potato fields. By this isolation, diseases that may occur in other fields cannot be transmitted to the seed farms by insect carriers.

When the plants are about six inches high, they are rogued for the first time. At this roguing, any Spindle Tuber or weak plants are removed. Each Seed Farm is rogued four to six times a summer. Special emphasis is placed on the removal of weak plants, questionable diseased plants, maturity of line, and any other abnormality that may appear. Whenever a plant showing one of the undesirable characteristics is found, the entire unit is removed, regardless of whether or not the other plants are normal.

All seed is harvested and placed in storage until spring. At this time it is again tuber-unit planted, and rogued four to six times during the summer. In the fall it is harvested, and is known as Foundation Seed. Foundation Seed is then released to the growers who agree to plant it by the tuber unit method in an isolated plot, and to rogue it thoroughly. The growers plot then becomes the source of seed for his certified acreage the following year.

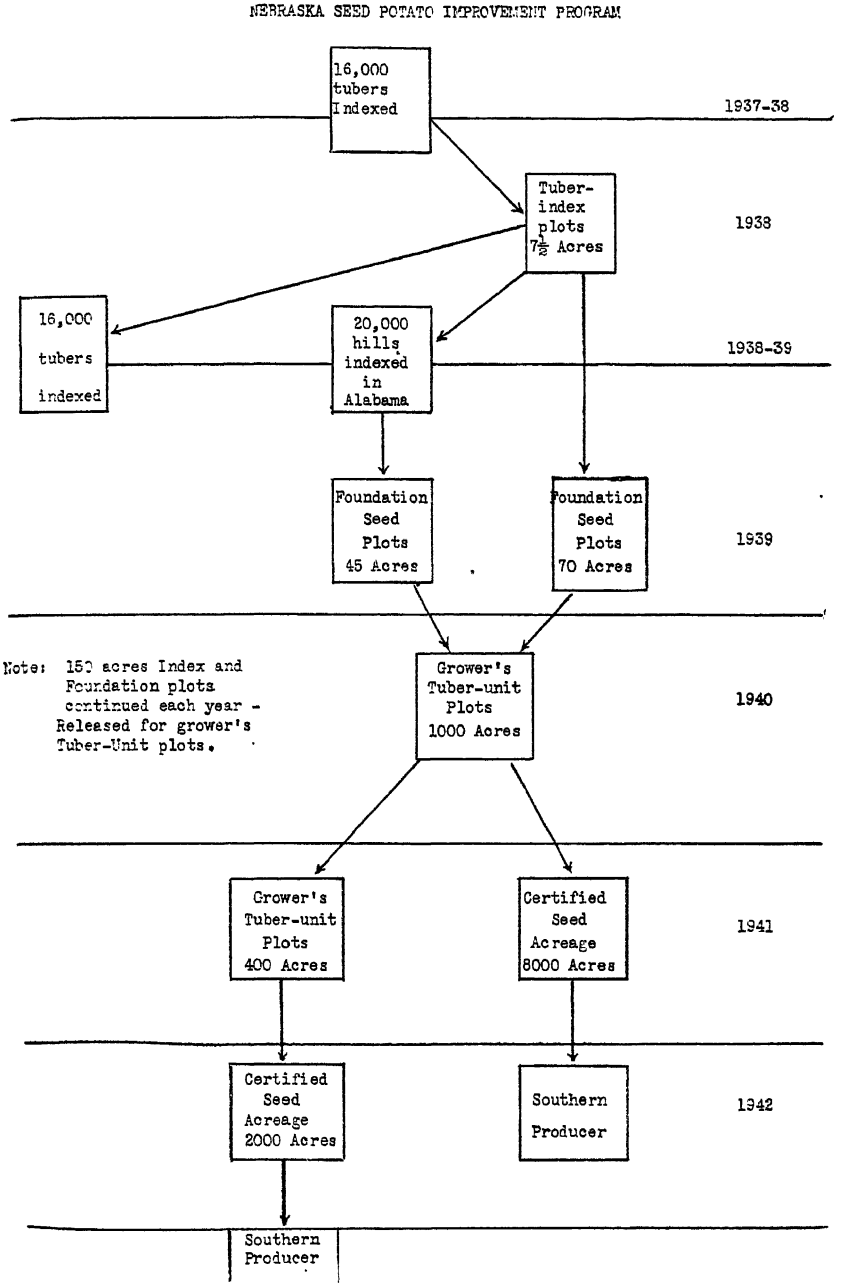
Throughout the many steps in the seed improvement program great care is used to prevent contamination with Ring Rot. All equipment used is thoroughly disinfected with HTH solution before and after each lot of potatoes has been handled. Storage space is disinfected with Copper Sulphate solution to kill organisms that might be present. New sacks are used for sacking of all Seed Farm potatoes to eliminate the possible contamination by Ring Rot from old sacks.

Clonal Lines

In order to propagate the established clonal lines, notes are taken on several hundred units of each strain being produced. Detailed descriptions of plant type and trueness of maturity are made. In the fall, these units are harvested separately, yields noted, and some discards made if the yield is small. The entire unit is kept separate and planted as a renewed clonal line the following year. As rapidly as possible, all but one of the original selections is discarded, and this one becomes the source of continued production.

Results of the Program

The chart indicates the various steps in the production of the


NEBRASKA SEED POTATO IMPROVEMENT PROGRAM
16,000 tubers Indexed
1937-38
Tuber-index plots 7½ Acres
1938
16,000 tubers indexed
20,000 hills indexed in Alabama
1938-39
Foundation Seed Plots 45 Acres
Foundation Seed Plots 70 Acres
1939
Note: 150 acres Index and Foundation plots continued each year - Released for grower's Tuber-Unit plots.
Grower's Tuber-unit Plots 1000 Acres
1940
Grower's Tuber-unit Plots 400 Acres
Certified Seed Acreage 8000 Acres
1941
Certified Seed Acreage 2000 Acres
Southern Producer
1942
Southern Producer

foundation seed potatoes. By such a series of steps, the grower in Nebraska is able to acquire entirely new seed for his certified plantings. Such new seed supplies him with a stock which is very low in disease content, from which he will plant his commercial certified acreage. Production from this commercial acreage is shipped to the southern grower.

SUMMARY

Indexing is the chief step in the Seed Improvement Program in Nebraska.

Two types of indexing are performed, indexing of tubers in the greenhouse, and indexing of hills in the south.

Other steps in the program include tuber unit planting and roguing.

Disease percentages are lowered in certified seed by application of indexing, tuber unit planting and roguing.

THE PRODUCTION OF SEED POTATOES IN THE STATE OF SAO PAULO[1]

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The rapid increase of the population in some States of Brazil and especially the rapid development of cities like Rio de Janeiro and São Paulo in the last twenty years has encouraged the cultivation of crops which had previously been given little attention. An outstanding example of this is the potato crop.

In nearly every country potatoes are planted for two principal purposes, for the market and for the production of seed. As in other countries, likewise in Brazil, the growing of market potatoes preceded those of tubers for seed purposes. The centers of potato production arose especially in the neighborhood of the great capitals. Cotia, a little town situated in a distance of only 30 km. from the capital of São Paulo, became the chief center of potato production in this state. The counties of Teresopolis and Nova Friburgo, not far from Rio de Janeiro, have long supplied Brazil's capital with potatoes.

[1]São Paulo, Brazil.

In all these centers of potato production, degenerating effects of virus diseases have been observed for a long time. In Cotia, for example, by buying a stock of good seed potatoes we may produce three successive potato generations. In the fourth generation, however, the production is, in general, so low that the crop becomes uneconomical. Therefore, it was necessary for the state of São Paulo to import a certain quantity of seed potatoes from other countries every year, largely from Holland and Germany. In table 1 is shown the number of boxes of potatoes imported from 1935 to 1940.

TABLE 1.—*Number of boxes (of 30 Kg)*

	Germany			Holland				
	Konsuragis	Other Varieties	All Varieties	Eigenheimer	Bintje	Eersteling	Other Varieties	All Varieties
1935/36	500	1206	1706	30769	—	—	112	30769
1936/37	5152	1112	6264	82437		11306	560	94243
1937/38	9905	1573	11478	41302	2027	9610	12487	65426
1938/39	2228	1374	3602	28332	4490	2540	981	36343
1939/40	—	—	—	29785	3348	3696	350	37179

Data furnished by Dr. J. B. de Castro. "Chefe da Seccao de Raizes e Tuberculos do Instituto Agronomico de Campinas."

In order to be able to interpret these figures correctly, it must be pointed out that the seed potatoes imported from Europe represent only a small part of those annually planted in the state of São Paulo, where two crops are planted every year.

The "summer crop" is planted during the months of January and February, the "winter crop" between August and October. The tubers imported from Europe have generally arrived here during the months of November and December and have served to supply a part of the demand of the summer crops. Those necessary for the winter crop are acquired from Paraná, where potatoes of an unknown variety and origin are multiplied under very favorable climatic conditions. These potatoes are, of course, considerably cheaper than those imported from other countries, but are far from being true to variety and free from serious plant diseases. They represent the almost single source of seeds for the winter-crop in São Paulo. From an economical point of view, there exists a real difference between the selected seed im-

ported from Europe and the tubers acquired from Paraná, because the latter can be used for only one year for planting, whereas the imported tubers furnish seed for three successive plantings.

With the extension of potato growing in São Paulo, the difficulties associated with these two chief sources of potato seed, became more and more apparent.

The seed from Europe was too expensive, was often not acclimatized to our soil and weather conditions and produced good yields only in the second generation. Besides that, there could never be entirely excluded the danger of importing, along with this seed, certain disease-producing organisms which had not yet been introduced such as *Synchytrium endobioticum* (Schilb) Perc. *Phythorimaea operculella* (Zell) and *Spongospora subterranea* (Wahr) Johnson.

On the other hand, the seed potatoes from Paraná presented an extremely high percentage of varietal mixtures and were heavily infected with the causal organism of bacterial wilt and soft rot. Since the organism causing bacterial wilt may survive in the soil for five years or longer and attack the potato, as well as other crops, this source of seed, too, was not very desirable.

There arose a serious problem of finding seed potatoes of good quality, at reasonable prices for farmers with relatively limited means. This problem, which arose before the war, became of increasing importance after the outbreak of hostilities, which prevented the import of seed potatoes from other countries. The ideal solution of this difficulty would be the production of good seed in our own state.

Fortunately, the war found us well prepared for this purpose. In the mountainous district of Serra da Fartara in the state of São Paulo, situated 300 kms. north of the Capital, we had been experimenting for many years with the degeneration disease of the potato. We knew, that the growers in that region had multiplied the same stock of potatoes twenty and more times, under economical conditions. With these observations, we began, in 1937, to study the dissemination of virus diseases in potato fields located in this mountainous district as well as in the plains. These experiments were started with a lot of specially selected tubers of the variety Eigenheimer, which we received from Prof. H. M. Quanjer, "Director van het Instituut voor Phytopathologie", Laboratorium voor Mycologie en Aardappelonderzoek, Wageningen, Netherlands. One hundred and fifty of these tubers were cut in two halves, and were then labeled "A" and "B" respectively.

All of the latter halves were planted in a plot at an altitude of 1200 m. The others were planted nearer to the Capital, at an altitude

of 700 m. The behavior of all these plants was observed during six successive generations, under the same conditions of altitude. Each year three field inspections were made and the numbers of all the plants, showing degeneration diseases, were noted on maps of the fields. Besides, on each inspection trip, material of suspected plants was brought to our laboratory in São Paulo, where sap inoculations were made in experimental plants of *Datura stramonium, Nicotiana tabacum* and *Nicotiana glutinosa.* In every one of the six generations the yield of each plant was obtained. It was soon demonstrated that in the mountainous region the degeneration diseases were disseminated much more slowly than at lower levels. (3,4)

Based on these experiments, there was founded on the 3d of December 1939, in the mountainous district, a seed potato-growers' cooperative. This cooperative, from its very beginning, enjoyed the following assistance from the various departments of the state:

1. Certified seed potatoes, from other countries, furnished the members of the cooperative.

2. Regulations and standards for the certification of seed potatoes in the state of São Paulo, relating to cultural conditions, disease tolerance, variety purity and quality were established.

3. A state certification service, composed of authorized officers of the Department of Agriculture was given supervision of the certification regulations.

4. Preference was granted to certified seed potatoes both with reference to sale and transport.

To every one of these points I shall give some further explanations.

1. The last lot of seed potatoes, imported from Holland, before the war, consisting of 1800 boxes of the variety Eigenheimer and 200 of the variety Bintje, was requisitioned by the state and distributed, gratuitously among the seed-potato growers. Later, some other potato varieties which had been multiplied for a number of years in this district, and which were relatively free from disease, were admitted for certification.

2. In order to have seed certified it is required that the crop be grown at an altitude of 1000 m. or more. The other regulations are similar to those in effect in the United States.

It is also required that all weeds belonging to the family of Solanaceae be removed from the field and its immediate vicinity.

The fields must be kept well sprayed against blight and insects, which act as vectors of virus diseases. After harvest the tubers are

given a bin inspection. Later, they are graded and disinfected under the supervision of the inspector.

TABLE 2.—*Maximum disease tolerance*

	1st Inspection	2nd Inspection	3d Inspection	Bin Inspection
	Per Cent	Per Cent	Per Cent	Per Cent
Bacterial wilt and soft rot	0.0	0.0	0.0	0.0
Total of virus diseases		10.0	5.0	
Total of secondary diseases (Rhizoctonia and Blackleg)		10.0	5.0	
Total—all diseases plus 2 per cent varietal mixture	30.0	20.0	10.0	
Tuber rot				5.0
Internal brown spot				10.0
Hollow heart				10.0
Root knot				20.0
Common scab and other skin diseases				30.0
Silver scurf				30.0

It is obvious that the allowances for diseases in our state are higher than is usual in other countries. But we thought it more useful to establish disease tolerances, which are within the possibility of our growers, and which at the same time are enforceable, rather than set up standards which exist on paper with only simply a theoretical significance.

3. In order to carry out the certification regulations three agronomists and three auxiliary officers were stationed in the section where the seed was grown. These men are assisted by the competent members of the staff of the Biological Institute at São Paulo.

In addition to the certification work, the staff set up, in specially isolated fields, small experimental plots to test all the potato varieties admitted for certification. The seed for these experimental plots was harvested from healthy and vigorous plants selected and staked among the plants in the various fields. These tubers furnished the material for tuber units in the experimental plots.

These experimental fields are intended to provide the state of São Paulo in the future with a stock of really good seed potatoes.

4. The carefully graded and disinfected seed tubers are placed in clean wooden boxes, every one of which is provided with an official tag on which is noted the number of the grower, the name of the va-

riety, grade of the tubers and date of the disinfection. The boxes are closed and sealed in the presence of an official inspector. The box is provided with an official certificate. The seed potatoes thus produced bring considerably higher prices than any other seed and may be shipped by railroad freight, free of charge, within the state of São Paulo.

With regard to the results we shall first consider the observations about plant diseases.

In some fields, recently cleared, it was thought that potatoes could be grown free from disease. At the first field inspection, however, it was apparent that seed potatoes of the variety Eigenheimer, imported from Holland, showed a very large number of plants infected with virus diseases. That this seed was infected when we received it is apparent from the fact that the infection was found uniformly in all fields planted with seed from this source.

Laboratory experiments conducted in São Paulo demonstrated that the virus carried by more than 50 per cent of this seed belongs to the Y-virus group (9). We could not confirm, as reported in the Dutch literature (3), that the Y-virus commonly found in Holland, and named there Stippelstreepzickte, causes less injury than the normal type of the Y-virus. It was necessary, therefore, that we insist that the Eigenheimer variety be rogued very carefully, thus causing serious loss to the grower. Fortunately, the Bintje variety showed much less disease and required less roguing.

Apart from the virus diseases, the Eigenheimer variety suffered very little from other plant diseases and pests the first year. Subsequently, bacterial wilt and black-leg became more prevalent, resulting from the fact that the variety was grown in fields previously planted with potatoes. It is of interest to report the appearance, in these fields, of a disease named rust ("ferrugem") by the growers. This disease is characterized by a dirty brown discoloration of the leaves, with the edges folded downwards and with a special lustre of the lower surface. This disease, described by A. S. Costa (1) is caused by mites (*Acarus*). Another disease, which has occurred recently in higher incidence, in spite of the careful disinfection of the seed tubers, is the silver scurf, caused by *Spondylocladium atrovirens*. We have the impression that this disease is worthy of more attention than is given to it in general. Even if the fungus does not enter the cells of the living tissue, it is possible, that tubers spotted by silver-scurf may be more easily attacked by secondary parasites than healthy tubers (2).

Referring now to the quantitative development of the seed, we have to stress from the beginning, that we could not expect large yields dur-

ing the first years of selection in view of the necessity of roguing a large percentage of the plants.

Even so, the production of seed potatoes in the state of São Paulo is increasing from year to year, actually supplying a part of the seed demand of São Paulo as well as of other states of Brazil. In the four seasons, two in 1940-'41 and two in 1941-'42, the total production was 31,774 boxes.

Finally for the American reader it may be of interest to know some outstanding characters of the seed-potato production in São Paulo.

In the first place, we have the situation arising from the planting of two crops each year in São Paulo. In order to make this possible we can plant only early or medium season varieties. This is easily understood when it is pointed out that our rainfalls are not uniformly distributed among the four seasons of the year but are much heavier, and occur at more frequent intervals, during the summer months. The two crops must, therefore, be planted in eight months (September-May). This means that potatoes harvested in December must be used for seed in January or February.

Here in Brazil also, the consumer demands a smaller size seed potato than is the case in the United States. The seed potatoes, sold by the cooperative, are divided for commercial reasons into four classes, ranging from 30 to 60 gms. The usual procedure here is to plant whole rather than cut seed both for commercial potato production and for the production of seed potatoes. Potato varieties which produce very large tubers will not find a very good market in Brazil for seed purposes.

It must be realized, too, that the market in São Paulo prefers a yellow potato. In Rio de Janeiro, however, a white-fleshed potato is in greatest demand.

Naturally, the American potato grower will be interested in the possibility of finding a market for certified seed potatoes in the state of São Paulo. As previously indicated most of our seed came from Holland and Germany. Fields planted with this seed revealed the presence of viruses belonging to the group of the potato Y-virus. It was not considered advisable to import at the same time potatoes which harbored the X-virus (healthy potato virus) due to the danger of the possibility of a simultaneous attack by the X and Y virus. Unfortunately, many of the American potato varieties belonged to this group. This, coupled with the fact that the São Paulo market prefers very early varieties with small, yellow tubers, did not seem to warrant the importation of American varieties.

More recently the situation has become more promising for the admission and distribution of American varieties throughout São Paulo. In the first place, our growers have a better appreciation of the need for complete isolation of potatoes grown for seed purposes. In this way they can avoid the spread of virus diseases. Again, in recent years the plant breeders in the United States have developed potato varieties which are free from the healthy potato virus. The importance of certain market preferences likewise assumes a less important rôle, since satisfactory seed potatoes can no longer be imported from Europe.

In view of these circumstances, it seems to be of importance that our state, as well as the United States, conducts experiments to determine the behavior of American certified seed potatoes in São Paulo. Experiments of this kind have already been started here with six varieties of certified seed from North Dakota.

It would be gratifying indeed, if these experiments would be the forerunners of commercial relations between Brazil and the United States on a new and promising sphere.

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COMPILATION OF RESULTS IN CONTROL OF POTATO RING ROT IN 1941

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COMMITTEE REPORT

The committee appointed by the American Potato Association for the purpose of stimulating and coordinating research on ring rot caused by *Phytomonas sepedonica* has again made a survey to determine the extent of the occurrence of this disease in the United States in 1941. On the basis of this survey, the committee submits the following report:

Replies received from 38 states reveal that in 17 states the disease was less prevalent than a year ago, whereas eight states reported the disease more widespread than in 1940. In one state 22 per cent of the carload lots shipped in 1940 contained ring rot, whereas in 1941 only 6 per cent showed the disease. Another state mentioned that during the last 2 years the losses in one county alone were $200,000 whereas this year, with greater care in handling the seed, the loss did not exceed $10,000. Most of the states attributed the decrease in ring rot to the campaigns that were conducted during the winter through meetings and publicity on control measures; to change in seed stocks; and

[1]Pathologist.

to the low price of certified seed in 1940, which enabled more growers to plant certified seed.

The disease is most serious in home gardens and on farms where little attention is paid to the source of seed. Although in many cases the planting of certified seed has given satisfactory results, in some instances the results were disappointing. One state reported the distribution of several carloads of certified seed potatoes that contained enough ring rot to produce from 10 to 50 per cent plant infection. The consensus of opinion is that the outlook for control is good as long as the certifying agencies in the seed-producing states maintain rigid control.

Attention was called to the difficulty of accurate diagnosis of the disease in the field,—especially after an early frost. In such cases and in some others, the inspector will have to rely on examination of the tubers in the bin. In order that a more complete and thorough inspection may be made it is recommended that in addition to field inspection at least four 25-pound random samples for each 1,000 bushels stored be examined by cutting each individual tuber. Suspected tubers should be examined under fluorescent light or smears should be made for examination under the microscope. Because the tuber symptoms become more distinct later in the season, it is desirable to make the bin inspection as late in the winter as possible.

More detailed experiments on the damage caused by planting seed containing a trace of ring rot should be conducted. More information is needed on methods of disinfecting bags, crates, storage houses, and farm machinery. The educational campaign to inform the growers of the seriousness of this disease and its occurrence in non-certified potatoes should be continued.

T. P. DYKSTRA, *Chairman*
R. W. GOSS
J. G. LEACH

COMMITTEE TO COORDINATE RESEARCH ON NEW AND UNUSUAL POTATO DISEASES.

The ring-rot disease is being studied in different parts of the country, and, on the recommendation of the committee, the potato project of the U. S. Department of Agriculture is continuing its function of compiling the reports on this disease as submitted by the different states. Many of the states that are investigating the ring-rot disease of potatoes have agreed to take part in this nation-wide program and have submitted reports. These are not necessarily complete and

conclusive, and contain generally only the results obtained during the 1941 season.

The cooperating states and investigators who have submitted reports are as follows:

Colorado:	D. P. Glick, R. Manuel, J. G. McLean, W. A. Kreutzer, and G. M. List
Florida:	A. H. Eddins
Idaho:	J. M. Raeder
Kansas:	O. H. Elmer
Maine:	R. Bonde
Michigan:	J. H. Munice
Minnesota:	Carl J. Eide
Montana:	G. H. Starr, W. A. Riedl
West Virginia:	V. E. Iverson and F. M. Harrington
Wyoming:	J. G. Leach
U. S. Department of Agriculture, Beltsville, Md.	Lillian C. Cash

A report on investigations of the ring rot of potatoes in Canada was prepared by H. N. Racicot of the Central Experimental Farm, Ottawa, Canada, and is also incorporated in this compilation.

Determining the Most Effective Method of Inoculation

Since it is important in studies on ring rot to be able to produce infection at will, the Wyoming Experiment Station conducted a test to determine which method of inoculation gave the most reliable results. The plants inoculated were tested for the presence of the ring-rot organism at approximately 2-week intervals to get the rate of ring-rot development, as well as the amount of ring rot at the final check-up.

The results (table 1) indicate that ring-rot symptoms appeared earlier where the hypodermic needle was used in inoculation through sprouts. It was immaterial whether a contaminated knife with a stainless steel or a non-stainless steel blade was used. Smearing the cut surface of tubers with a ring-rot-infested tuber did not increase the amount of ring rot. The bacterial suspension method produced later symptoms and slightly less ring rot than any of the other methods. Less disease was produced with whole than with cut tubers.

TABLE I.—*Methods of inoculation and the rate and amount of ring-rot development. Wyoming.*

METHODS OF INOCULATION	PLANTS SHOWING RING-ROT SYMPTOMS AT DIFFERENT DATES (PLANTED MAY 21, 1941)			
	JULY 24	AUG. 6	AUG. 20	SEPT. 4
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*
1. Tubers cut and dipped in bacterial suspension	8.3	40.0	75.0	91.7
2. Tubers cut and smeared on cut surface with ring-rot tuber	13.7	60.8	95.0	98.3
3. Hypodermic needle through short sprouts	49.7	88.5	94.0	97.0
4. Contaminated cutting knife (stainless steel)	20.0	71.0	88.5	100.0
5. Contaminated cutting knife (not stainless steel)	26.1	82.7	98.3	100.0
6. Whole tubers dipped in bacterial suspension	5.0	25.0	55.0	70.0

The effect of four methods of inoculation was tested in Beltsville on plants growing in the greenhouse, using as inoculum a suspension in 5 cc, sterile tap water of a 4-day agar slant culture on Burkholder's special medium.

1. Hypodermic inoculations were made 2 mm. from the eyes of the seed pieces, and the uninoculated eyes were removed.
2. Inoculations of cut seed pieces were made by soaking the cut surface immediately upon cutting in the bacterial suspension for 15 minutes and planting immediately.
3. Whole tubers were treated in the same manner as in No. 2.
4. Shoots 8 to 10 inches high were inoculated by hypodermic injection of a suspension of the ring-rot organism, inoculating one shoot of a plant.

Two months after inoculation the stems were examined microscopically for the ring-rot organism, using the gram stain. Method

2 gave the greatest percentage of infection; No. 1 gave a high percentage of infection; No. 4 gave a low percentage, and No. 3 produced none.

The effect of different concentrations of bacterial suspension used in hypodermic inoculations in the eyes of tubers was tested. Forty plants were used in each series. Bacterial suspensions were made by adding 5 cc. of sterile tap water to each of four agar slant cultures and pouring the suspension into a single beaker. This suspension was used to inoculate series A, after which the remainder was diluted with an equal amount of water for series B thus making the dilution equivalent to 10 cc. per culture. For series C the inoculum used for B was again diluted with an equal amount of water to make the dilution equivalent to 20 cc. per culture. The concentration of the bacteria in the original 5 cc. suspension was determined by the color chart for white precipitate methods.[2] It checked with the third place for white precipitate, or 150 parts per million chlorides.

The percentage of infection was high in the stalks but low in the daughter tubers. It was only possible to run this test 2½ months, which may account for the slight amount of tuber infection.

TABLE 2.—*Results of inoculation with varying concentrated suspensions of Phytomonas sepedonica. Beltsville, Md.*

SERIES	DILUTIONS	INFECTION IN STALKS	INFECTION IN TUBERS
		Per Cent	*Per Cent*
A	5 cc. H_2O per agar slant.....	45.6	1.7
B	10 cc. do	72.0	8.3
C	20 cc. do	31.5	0.0

COMPARISON OF CAUSAL ORGANISM FROM INFECTED TUBERS COLLECTED FROM DIFFERENT STATES, AND THE USE OF THESE IN INOCULATION STUDIES

The Wyoming Station collected ring-rot tubers from California, Kansas, North Dakota, Montana, Minnesota, Maine, New Jersey, and Oregon. again 3 weeks later from the same tubers. About 3 weeks later plant-

[2]Spurway, C. H. 1935. Soil testing, a practical system of soil diagnosis. Mich. Agr. Exp. Sta. Tech. Bull. No. 132, pp. 1-125.

ings were made with healthy tubers (five in each case) and inoculated as follows: ((1) Directly from the infected tubers by the smear method on the cut surface and the needle stab through the eyes, (2) from cultures isolated 18 days before and inoculated by the needle stab method, and (3) from cultures isolated about 40 days before by the same method of inoculation.

The plants were inspected in the field for ring-rot symptoms which were recorded for each lot. No difference in symptoms could be observed in the infected plants inoculated by the organism isolated from tubers obtained from different states. The infection was 100 per cent from the tubers whether the inoculations were by the smear or the needle-stab method. The average infection from cultures 18 to 20 days old was 56 per cent, and from those 40 days old, 12 per cent. Slides were made from all the cultures and tubers at the time of inoculation. These showed that in cultures approximately 18 days old the ring-rot bacteria were very numerous, accompanied usually by few soft rot bacteria. Cultures approximately 40 days old contained few ring-rot bacteria and proportionately more soft rot bacteria. This indicates that the purification of cultures is important when isolations from tubers are involved. It was therefore recommended that healthy tubers should be inoculated with ring-rot cultures and grown in sterilized soil in pots under greenhouse conditions so that infected tubers may be available for use in inoculation. Infected tubers can be kept for relatively long periods and have the advantage over artificial cultures in that the bacteria will remain pathogenic as long as the tubers persist.

Testing Media for Culturing *Phytomonas sepedonica*

Various modifications of culture media were tested in Beltsville to find one favorable for the growth of *Phytomonas sepedonica*. A modified potato-dextrose medium gave the most satisfactory results. This is prepared as follows: To approximately 300 grams pared and sliced potatoes add 1,000 cc. of water. Cook in a steamer until the potatoes break up. Then pour water off and on the potatoes several times in order to extract as much nutrient as possible. Filter through cheese cloth and make up to 1,000 cc. After adding 12 grams agar, 5 grams peptone, 6 grams dextrose, and 1 gram yeast extract, heat in a steamer until dissolved. Adjust with N/5 NaOH to 6.8 or 6.9. Finally, filter through cotton, tube and sterilize. This medium has certain definite advantages: it is comparatively easy to make colonies appear

in 3 to 4 days on agar plates; there is copious growth in 4 days on agar slants; and the organism retains its typical pathogenic rod form for at least 1 month.

Determining the Effect of a Mixed Culture of *Phytomonas sepedonica* and Soft-rot Organisms

The effects of mixed cultures of *Phytomonas sepedonica* containing respectively each of several contaminants often present in ring rot tubers were compared with *P. sepedonica* alone in inoculation studies in Beltsville. Seed pieces were inoculated hypodermically and planted in lots of 20 pots. There was little difference in the amount of infection on stalks; but the mixed cultures produced increased infection in the tubers, in comparison with the pure culture.

Table 3.—*Results of infection with Phytomonas sepedonica alone and in mixture with other organisms. Beltsville, Md.*

Cultures	Amount of Infection	
	Stalks	Tubers
	Per Cent	*Per Cent*
P. sepedonica alone	45.6	1.7
P. sepedonica + *B. subtilis*	68.4	65.2
P. sepedonica + *B. mesentericus*	52.4	No tubers formed
P. sepedonica + green fluorescent organism	56.7	20.6
P. sepedonica + culture No. 31	51.8	44.4

Rate of Movement of Ring Rot Organism after Inoculation

At Beltsville, tubers were inoculated hypodermically with a suspension of the ring-rot bacteria, held at room temperature, and examined to determine the progress of the organisms in the vascular bundles. After 2 months infection had spread 5 mm. to 10 mm.; after 3 months in 67 per cent of the tubers positive readings were obtained at 1 cm.

from the needle track, and in 23 per cent of the tubers infection had spread 2 cm.

Cut surfaces of seed pieces were placed in contact with bacterial suspension 10 minutes before planting. In 3 weeks infection occurred as follows: Shoot base, positive 4, negative 9; shoot at 5 mm. above base, positive 0, negative 13; tuber, at a depth of 5 mm. from inoculated surface, positive 1, negative 4. In 6 weeks all shoots were found to be infected. The distance of the organism from the point of inoculation varied in different shoots from 1 to 14 cm. All shoots examined emerged from the seed piece less than 5 mm. from the inoculated surface.

Latent Infection of Ring Rot

Inoculation experiments conducted in West Virginia in 1940 gave apparently negative results, since none of the inoculated tubers produced visible infection on the plants in the field or in the harvested tubers on inspection late in December. In 1941 as many as 57 per cent infected hills resulted when the stock was planted as whole tubers. Because there was no opportunity for transmission by the cutting knife, this would indicate that as high as 57 per cent of some of the seed lots were infected.

The significant point in these results is that insofar as ring rot was concerned, this experimental plot would have passed all requirements for certification, yet there was a very high percentage of potential infection in the seed stock. This indicates that under certain conditions the usual field inspection, coupled with bin inspection shortly after harvest, will not be sufficient to give a true picture of the amount of ring rot present.

No Spread of Ring Rot from Hill to Hill or from Row to Row

It was found in Florida that although 80 per cent of the plants in rows planted with diseased seed were affected with the ring rot in 1941, none of 358 plants originating from healthy seed and grown in the adjacent rows developed the disease. None of 722 plants comprising the progeny of tubers produced similarly in 1940 in rows adjacent to affected plants showed any symptoms of the disease in 1941. No signs of ring rot were detected in 28 plants originating from healthy seed and grown in the same row in hills 1 foot distant from 14 hills that were planted with diseased seed pieces, 10 of which rotted and 4 of which produced plants affected with ring rot.

In Michigan ring-rot-infected tubers were planted every fourth hill along the row with healthy tubers. The healthy tubers were planted first and the ring-rot tubers inserted in the proper place. The rows were replicated three times, and in no case was there any spread from the ring-rot-infected hill to the healthy adjacent hill. This field was irrigated with an overhead sprinkling system once during the season.

Ring Rot Spread by Handling Seed after Cutting

In a test in Florida healthy seed was cut with a contaminated knife and planted immediately. Of 250 plants 9.2 per cent were affected with ring rot. But when a similar lot of seed was cut and stored in a jute bag for 36 hours before planting, 23 per cent of the plants developed the disease. In another test, 148 tubers from a stock affected with ring rot were cut into two pieces each. One piece from each tuber was planted immediately, and the other pieces were placed in a basket and later transferred to a jute bag where they were kept for 24 hours before planting. Seed pieces planted immediately after cutting produced plants of which 10 per cent were affected with ring rot, seed pieces stored in the jute bag for 24 hours produced plants of which 31 per cent were affected with the disease. Possibly the additional handling of the cut seed caused the bacteria to be spread over a greater number of seed pieces and thus increased the amount of infection.

No Overwintering of the Ring-rot Organism in Soil

No ring rot was detected in tops and tubers of 552 potato plants originating from healthy seed and grown in Florida in 1941 in soil where 25 to 64 per cent of the plants were affected with ring rot in 1938, and later seeded with 5 barrels of diseased tubers to increase the infestation. None of the 2,700 plants grown in the soil during the 3 years since 1938 has shown any signs of ring rot. Furthermore, no ring rot developed in 784 plants of the first generation progeny and in 341 plants of the second generation progeny of tubers produced in this infested soil in 1939. There has been no loss from ring rot at Hastings in potato crops planted with healthy seed in a number of fields where the disease was present the preceding year.

For three successive seasons experiments were conducted at Ottawa, Canada, on the overwintering of *Phytomonas sepedonica* in the soil. The soil was contaminated in the fall by incorporating a heavy

application of decayed and partly rotted tubers from ring-rot-infected plants. In the spring, freshly cut healthy sets were planted in this soil. At no time did any of the plants from these sets ever become infected, although one year some of the partly decayed tubers overwintered and produced diseased plants the next season; therefore, it is believed that the ring-rot organism does not overwinter in the soil under Ottawa conditions in such way as to cause new infection.

In Wyoming ring-rot-infected tubers were placed approximately 4 inches under the soil and on top of the soil and left there during the winter to determine whether the bacteria would survive. Also, burlap sacks were contaminated with ring-rot bacteria, and one lot of these was placed outside and another inside the storage cellar during the winter months. At planting time each lot of bags was soaked in water and healthy cut seed pieces were dipped in the wash water just before being planted. The infected tubers left in the soil during the winter were also used, as well as the soil around these tubers, to make suspensions in which healthy cut seed pieces were dipped. These were planted and the resulting plants checked for the presence of ring rot. (See table 4).

TABLE 4.—*Overwintering test of ring rot bacteria from different sources. Wyoming.*

SEED INOCULATED	SOURCES OF INOCULUM	RING ROT
		Per Cent
Healthy seed pieces	Contaminated sacks left outdoors during winter	45
Do	Contaminated sacks kept in storage cellar	10
Do	Tubers kept in outside soil	2.5
Do	Soil surrounding infected tubers left outside during winter	2.5

Considerable ring rot resulted from the test in which washings from the burlap sacks left outdoors were used as the inoculating agent. There was much less ring rot in the test where burlap sacks left in the storage cellar were used as the source of inoculum. There was some evidence that the organism may overwinter in the tubers left outside in the soil. The same was true of the soil taken from around these tubers. Thus, there is some evidence from this test that the bacteria are able to

live over in the soil or in the tubers remaining in the soil under the Wyoming conditions.

In continuing the study of contaminated sacks as a source of ring-rot infection, in Minnesota, seed was planted on the 19th of May, 1941, which had been shaken in sacks emptied on the 25th of March. The sacks contained 1.5 to 27 per cent of ring-rot tubers at the time they were emptied and were kept in a cool, dry place until they were used for the cut seed pieces. Plants from the seed shaken in nine sacks were found to be infected at digging time.

The survival of *Phytomonas sepedonica* in soil was studied in Minnesota under controlled conditions involving the following variables:

1. Soil sterilized and non-sterilized.
2. Source of bacteria used to contaminate soil: pure cultures and yellow material from the vascular ring of diseased tubers.
3. Place of storage—
    a. In a laboratory at 65°to 75° F.
    b. In a refrigerator at about 35° F.
    c. Out of doors.

Pint fruit jars of soil involving all possible combinations of the above conditions were prepared during the winter of 1940, and successive samples were tested for the presence of *P. sepedonica* at intervals of a month or 6 weeks. This was done by pouring the soil over freshly cut seed pieces and allowing them to grow in pots in the greenhouse. The presence of the disease and gram-positive bacteria in the plants was taken as evidence of the survival of the bacteria in the soil. Table 5 shows the maximum time in which the bacteria lived in the soil as determined by these methods.

Apparently *P. sepedonica* survives less than a month in non-sterile soil at temperatures high enough for the growth of most organisms. Freezing or near-freezing temperatures protect it for some time. These results raise doubts about the ability of *P. sepedonica* to survive for any length of time anywhere, it must live saprophytically, and where the temperature and moisture conditions permit the growth of competing saprophytic bacteria and fungi.

Seed harvested with a contaminated digger in the fall of 1940, picked in a contaminated basket, and stored in a contaminated sack produced a few ring-rot plants.

TABLE 5.—*Survival of P. sepedonica in sterile and non-sterile soil under different conditions. Minnesota.*

STORAGE CONDITIONS	SOURCE OF INOCULUM	LATEST SURVIVAL DATE[1]	
		IN STERILE SOIL	IN NON-STERILE SOIL
		1941	1941
Outside	Pure culture[2]	March 13	February 11
	Diseased tissue[2]	March 13	March 13
35° F.	Pure culture	April 11	January 1
	Diseased tissue	March 13	March 13
Laboratory	Pure culture	February 11	0[3]
	Diseased tissue	February 11	0

[1]Last test made.
[2]Soil was contaminated with the diseased tissue on November 29, 1940; with the pure culture on December 4, 1940.
[3]The non-sterile soil stored in the laboratory was apparently free from ring rot bacteria in a month (Jan. 1, 1941) after the experiments were started.

EFFECT OF DATE OF PLANTING ON THE DEVELOPMENT OF RING ROT

Experiments were conducted in Wyoming to determine the effect of date of planting on the occurrence of ring rot. Two rows, of 40 hills each, were planted at four planting dates with 10-day intervals to study ring-rot development. The cut seed was inoculated by dipping it in a suspension of the ring-rot bacteria just before planting.

In the earliest planting (May 11) the stand, as well as the ring-rot percentages, were considerably reduced as compared with the later plantings. The time required for visible ring-rot symptoms was much longer than in the case of the later plantings, due in part to the longer time required for germination of the seed. However, ring rot actually showed up in the second planting (May 21) before it did in the earliest planting (May 11). Ring rot appeared in the latest planting (June 11) sooner after planting than it did in any of the other lots, although the difference was slight when compared with the planting of the 1st of June.

DISINFECTING CUTTING KNIVES

During the season of 1941 numerous experiments were conducted in Wyoming to obtain practical information on the control of ring rot.

An almost disease-free lot of Bliss Triumphs was used in the tests. The treatment rows consisted of 10 hills planted 18 inches apart in the row, with four replications arranged in a random manner. Ring-rot readings were made on the basis of plant symptoms.

TABLE 6.—*Effect of date of planting on the development of ring rot. Wyoming.*

DATE PLANTED	STAND	RING-ROT	TIME ELAPSING BETWEEN PLANTING DATE AND FIRST VISIBLE RING-ROT SYMPTOMS
	Per Cent	*Per Cent*	*Days*
May 11	77.5	40.3	88
May 21	97.5	98.7	67
June 1	95.0	90.8	63
June 11	98.5	100.0	59

In an attempt to find suitable disinfectants to replace mercuric chloride, 24 compounds were tested, some in as many as five concentrations, making a total of 62 treatments. These tests were made by dipping a cutting knife for 10 seconds into the disinfectant to be tested, and immediately using it to cut a healthy tuber in half. This dipping was repeated before each tuber was cut. The seed pieces were planted on the Agronomy Farm at Laramie, Wyo.

As in the past, mercuric chloride and acidulated solution of mercuric chloride were highly effective; iodine was almost as effective; and Semesan Bel. Du Bay, Cinnex 20, and copper sulfate were relatively ineffective in the 10-second exposure. Formaldehyde (1:10) was also relatively less effective, except when used as both solution and vapor, when it was highly efficient. Ethyl alcohol gave poor results for this length of exposure. The following compounds, tried for the first time, were relatively ineffective at the concentrations used: Gentian violet, proliferol, furfural, and cuprocide. Ethyl alcohol plus mercuric chloride was slightly less effective than the mercurial alone. The chlorinated compounds, H.T.H., Steri-chlor, Gasklor (except that Gasklor was effective at 8,000 p.p.m.), were relatively ineffective with the 10-second exposure; while B-K was quite effective at the tested strength greater than 2,000 p.p.m. in the test. Lysol, 4-per cent, gave

good results, whereas Kreso dip was less effective. Boiling water in exposures of 5, 10, and 15 seconds gave good results and offers possibilities in the control of ring rot.

A number of chemicals were tested in Ottawa, Canada, as disinfectants for the knife used in cutting sets. A stainless steel paring knife was thoroughly contaminated by cutting into diseased tubers known to carry large numbers of *P. sepedonica,* dipped into the solution of the chemical to be tested for 10 seconds, then used immediately to cut small healthy tubers longitudinally into two sets. Two-per cent Lysol (a saponified cresol) was not effective, while 4-per cent and 10-per cent solutions were. Formalin (commercial 40-per cent formaldehyde) at 1/10, ½, and full strength was not effective. Semesan and Semesan Bel, 2-per cent solutions, were very ineffective. Mercuric chloride, 1:1,000 in water, was not effective; but the 1:500 dilution with either 1-per cent hydrochloric acid or 0.35-per cent hydrochloric acid (equivalent to Mercurnol at the rate of 32 fluid ounces to 20 gallons) was completely effective.

Deterioration of Cutting Knife Disinfectants

Experiments were conducted in Colorado to determine at what rate disinfectants deteriorate under practical conditions. When a rotary knife is used, the distinfectant is subject to contamination by tuber pulp, and soil from the surface of the tubers. Standard bacteriological methods were used to measure the strengths of numerous disinfectants at selected intervals during the actual cutting operations. When 1 pint of disinfectant was used a mercuric chloride solution (1:500 in water) became ineffective after two sacks had been cut; acidulated mercuric chloride (1:500 in 1-per cent hydrochloric acid) after two sacks; and a 1-per cent solution of iodine after four sacks. When 1 gallon of disinfectant was used, a solution containing 2,000 p.p.m. of chlorine lasted through eight sacks, 5-per cent phenol was not exhausted after 12 sacks (but severely damaged the seed pieces), and 2-per cent cresol was effective after 24 sacks. When amounts greater than 1 gallon were used, the efficiency increased slightly but not in proportion to the amount of disinfectant.

When the cost and rate of deterioration of the more common disinfectants were taken into consideration, it was tentatively concluded that the best cutting knife disinfectant would be boiling water, because the effectiveness of this disinfectant is merely a function of the temperature and because the cost is low in comparison with that of the chemical solutions.

TREATING INOCULATED TUBERS BEFORE CUTTING AND AFTER CUTTING

In Wyoming 30 different treatments were tested to find a disinfectant to replace mercuric chloride in the treatment of seed potatoes for control of ring rot. Few effective disinfectants are available that can be used to treat seed potatoes after cutting, although a number of them can be used previous to cutting the tubers.

All tubers were inoculated by dipping them in a suspension of the causal organism. A portion of these was dipped for the required time in the disinfectant and later cut into halves. Another portion was cut into halves and then dipped in the disinfectant to be tested. The tubers were then spread out and the surfaces were allowed to dry before planting.

From the standpoint of both ring-rot control and yield, the 1:500 solution of mercuric chloride gave some of the best results. The same was true of Mercurnol. Iodine in treatments of 15 minutes reduced ring rot to a minimum and gave good yields when used either before or after cutting. Lysol, 2 per cent, gave good yields in both cases but did not control ring rot so well as stronger solutions, which reduced yields when used on cut seed. In a general way, numerous disinfectants gave satisfactory control of ring rot, as well as good yields when used on whole seed, but few of them gave satisfactory yields when used on cut seed.

In Michigan in tests with chlorinated phenol at strengths of 1:1,000 and 1:2,000, corrosive sublimate at 1:500, and acidulated corrosive sublimate solution for tuber treatments, the acidulated corrosive sublimate severely injured the seed pieces and only 37 per cent of the tubers produced plants. There was no evident injury apparent from the other treatments. The acidulated corrosive sublimate was the only material used which seemingly prevented ring rot. The stand, however, was so reduced that using this material seems out of the question.

In Florida 100 large tubers were cut into four seed pieces each with a knife contaminated with *Phytomonas sepedonica* and one piece from each tuber was planted in each of our lots. Lot 1 was not treated, lot 2 was soaked in water at 124° to 126° F. for 4 minutes; lot 3 was soaked in 1:30 formalin solution at 124° to 126° F. for 4 minutes; and lot 4 was held for 24 hours and then soaked in 1:30 formalin solution at 124° to 126° F. for 4 minutes. All lots were covered with canvas for 1 hour after treating and then spread out and allowed to dry before

planting. The seed was not injured by the hot water treatment, but this treatment spread ring rot as 22.5 per cent of the plants grown from this seed were infected whereas only 6.5 per cent of the plants grown from the non-treated seed developed the disease. The hot formalin solution gave no control of ring rot because infection was 6.6 and 8.6 per cent in lots 3 and 4, respectively. The hot formalin injured the cut seed and reduced the stand of plants 54 per cent in the seed treated immediately after cutting and 30 per cent in seed treated 24 hours after cutting.

In Minnesota disinfectants were used on cut seed to prevent the spread of ring rot. Seed was cut with a knife drawn through a ring-rot tuber before cutting each seed tuber. These results are shown in table 7.

Because acetic acid has given promising results in the control of bacterial canker of tomatoes, and *Phytomonas sepedonica* is related in some ways to *P. michiganensis,* investigations were conducted at the Ottawa Central Experiment Station in Canada to determine if the ring rot organisms might be sensitive to low concentrations of acetic acid. Sets were cut from healthy tubers under a suspension of the ring-rot organism, allowed to stand 20 minutes, and dipped 1 minute into acetic acid solutions varying in concentrations from 0.25 to 5 per cent, allowed to dry completely, and then planted in the field. After 1 week some sets were dug to study the effect of the acid on cork formation and set decay. The acid greatly inhibited cork formation, particularly in the higher concentrations used, resulting in the rotting of sets and a high percentage of misses. Moderate disease control was obtained with the 5-per cent solution, but very low yields; the other concentrations gave very poor disease control, and also reduced yields. Acetic acid did not prove at all practical for the control of ring rot in cut sets.

TABLE 7.—*Percentage of ring-rot-infected hills from seed variously treated after cutting. Minnesota, 1941.*

TREATMENT[1]	TREATED IMMEDIATELY		TREATED 15 MINUTES AFTER CUTTING	
	AT HARVEST[2]	TOTAL	AT HARVEST	TOTAL
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*
Acid mercury	8.0	38.0	9.0	28.0
Cinnex Special[3]	8.0	25.0	4.0	8.7
Semesan Bel	45.3	71.7	20.0	46.0
Dust Treatment[4]	22.3	47.7	18.7	49.3
Check	54.7	85.0	56.3	84.3

[1]Seed was dipped about 2 minutes in acid mercury or 15 to 20 seconds in Cinnex or Semesan Bel. The dust was shaken over the cut seed as recommended by the manufacturer.

[2]Percentages are based on the number of hills with visibly rotted tubers at harvest time. Tubers from apparently healthy hills were stored until February and examined for ring-rot then. These figures were added to those found at harvest time to give the records.

[3]Cinnex Special contains yellow oxide of mercury and 1 per cent of iodine.

[4]The dust contained powdered mercuric chloride as the active ingredient.

Tests were conducted in Canada both in the greenhouse and in the field with various chemicals as disinfectants for cut sets. The sets were cut from healthy tubers with a knife contaminated by cutting through diseased tubers. In a few cases the knife was contaminated by dipping it into a suspension of a virulent culture of *P. sepedonica*. The sets were allowed to stand about 30 minutes before treating them, and then planted on the following day. The results are briefly as follows:

One-per cent copper sulphate solution used as a dip or as a 5-minute soak, and a 2-per cent solution as a dip, gave very variable results both in injury to sets and in control of ring rot. Formalin, 0.5-per cent, as a 10-minute soak, and 1-per cent as a dip, gave poor results and caused serious injury to sets. Semesan and Semesan Bel, 0.25-per cent and 2-per cent as dips, gave practically no control, although they caused no injury to sets. Lime-sulphur, 1.4-per cent, as a 1-minute dip and as a 5-minute soak, gave poor control, but no injury to sets. Iodine, 0.5-per cent in 1-per cent potassium iodide, and 0.5-per cent potassium

permanganate, gave no control of ring rot and caused no injury to sets. Mercuric cyanide, 0.2-per cent as a dip, and 0.2-per cent mercuric chloride in 1-per cent hydrochloric acid used as a dip, gave 97 per cent and 95 per cent control, respectively, and caused no injury to the sets.

No appreciable injury to sets and no appreciable control were secured with the use of a 5-per cent solution and 30 minutes of soaking of the following chemicals: Aluminum potassium sulphate, lead acetate, magnesium sulphate, manganese sulphate, sodium thiosulphate, calcium hypochlorite, and sodium thiocyanate. Sodium borate gave no injury to sets but gave variable control. Zinc chloride gave varying amounts of injury and moderate control. Potassium pyrosulphite and potassium dichromate killed practically all the sets. Potassium ferrocyanide and sodium sulphate killed 50 per cent or more of the sets, and gave only moderate control.

In Idaho the effect of various treatments was tested on Netted Gems, which contained 5 per cent infected tubers, using approximately 200 seed pieces in each treatment. After this seed was cut, without disinfecting either knife or cut seed, and planted with a 2-man planter, 88 per cent ring-rot plants developed; the seed pieces planted with a picker planter developed 81 per cent diseased plants. When the seed was cut with a knife disinfected with B-K (8,000 p.p.m.), 4.5 per cent diseased plants developed; when acidulated mercuric chloride solution was used 6.7 per cent ring rot developed. Five-per cent Lysol reduced the amount of diseased plants to 13 per cent; but 10-per cent formalin proved to be quite ineffective as a disinfectant, as 26 per cent of the plants showed ring-rot symptoms.

None of the various materials tested as a disinfectant for the cut seed showed any promise of control. In the checks where no disinfectant was used 89 per cent ring rot was evident. Acidulated mercuric chloride dip for 10 minutes gave the best results, but 24 per cent of the resulting plants showed ring-rot symptoms. Very little reduction in infection or none at all was caused by Semesan Bel, 1:1,000, Brilliant Green, or B-K at 8,000 p.p.m. dilution.

In Kansas seed pieces were cut with a knife previously contaminated by insertion into a ring-rot-infected tuber between every cut. One-half of the seed pieces of sack A was dipped 10 minutes in corrosive sublimate at 6 ounces to 25 gallons of water plus hydrochloric acid to give a 1-per cent concentration. One-half of the seed pieces of sack B was treated for 10 minutes in calcium hypochlorite at a concentration of 19 grams of 50-per cent calcium hypochlorite to 5 gallons of water. The other two halves of sacks A and B were left untreated. The two

untreated and the two treated lots of seed pieces were planted while still wet with a commercial potato planter in adjoining rows, approximately 550 feet long, in a field of commercial potatoes. A similar lot was planted on a different farm.

The results showed that a considerably higher percentage of the plants from the two treated lots of seed pieces were alive at harvest time than from the corresponding two untreated lots. There was little difference in the number of plants with decaying tubers at harvest time following either treatment or in the corresponding untreated controls. Yields were much greater from the treated than from the untreated lots. Higher yields were obtained from the lot treated with acidulated corrosive sublimate than from the lot that had been treated with calcium hypochlorite.

These tests like those conducted in Kansas in 1940 indicate the value of treating ring-rot-contaminated cut seed pieces with acidulated corrosive sublimate or calcium hypochlorite before they are planted. The treatment with acidulated corrosive sublimate is apparently the more desirable of the two methods tested, because it was followed by higher yields in both plots. On the basis of these tests, the corrosive sublimate treatment is recommended because it is also effective for the prevention of Rhizoctonia infection and seed piece decay.

Efficiency of Compounds as Storage Disinfectants

In Wyoming tests were conducted to determine different compounds as storage-cellar disinfectants by simulating conditions comparable to actual storage conditions. Short pieces of boards were inoculated by rubbing them with tubers infected with ring rot. These boards were left in the storage cellar. The various solutions were then sprayed on them at intervals of 30 minutes and 16 hours, and healthy cut tubers (10 for each test) were rubbed over these surfaces to pick up the ring-rot bacteria.

To test the effectiveness of the vapors, 2-quart fruit jars were used each with 250 cc. of the solution in the bottom of the jar. A narrow board was inoculated, as above, and put in each jar, this resting in each case above the solution and exposed to the vapors of the closed jar. At intervals of 5 hours and 24 hours the boards were removed and likewise rubbed with the cut portion of healthy seed pieces (10 for each treatment).

These seed pieces were planted and the plants examined later for ring rot to determine whether the treatments were effective. The results are shown in table 8.

TABLE 8.—*The effectiveness of chemicals as storage cellar disinfectants. Wyoming.*

DISINFECTANTS USED	RING-ROT RESULTING			
	CONTAMINATED BOARDS SPRAYED		CONTAMINATED BOARDS EXPOSED TO FUMES	
	TESTED 30 MIN. AFTER INOCULATION	TESTED 16 HOURS AFTER INOCULATION	TESTED 5 HOURS AFTER INOCULATION	TESTED 24 HOURS AFTER INOCULATION
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*
B-K, 2,000 p.p.m.	0.0	0.0	50.0	20.0
B-K, 1,000 p.p.m.	10.0	10.0	60.0	20.0
Furfural, 1:60	30.00	20.0	90.0	20.0
Furfural, 1:120	80.0	20.0	60.0	10.0
Steri-color, 1,000 p.p.m.	10.0	0.0	80.0	20.0
Steri-crlor, 1,000 p.p.m.	10.0	0.0	100.0	50.0
Formaldehyde, 1:120	30.0	0.0	60.0	40.0
Copper sulfate, 1 lb. to 50 gallons	10.0	0.0	[1]	[1]
Control, none	60.0	10.0	100.0	100.0

[1]Copper sulfate not tested for action of fumes.

In general, the fumes alone, even after 24 hours, were not so effective as the solutions acting for 5 hours. When tested after 16 hours the following solutions, when sprayed on the contaminated boards, gave good control of ring rot: B-K, 2,000 p.p.m.; Steri-chlor, 500 and 1,000 p.p.m.; formaldehyde 1:120; and copper sulfate 1 pound to 50 gallons of water. None of the fumes acting for 24 hours completely controlled ring rot.

ACCURACY OF THE ULTRAVIOLET-LIGHT METHOD FOR SELECTING RING-ROT-FREE POTATO SEED STOCK

To obtain further evidence regarding the ultraviolet-light method extensive greenhouse experiments were conducted in Montana during 1941. These were designed primarily to compare the accuracy of the ultraviolet-light method with the gram-stain method for selecting disease-free seed stocks. From a stock of Netted Gem potatoes that had shown considerable ring rot in previous gram-stain tests, 148 tubers were selected at random for ultraviolet-light examinations, 148 for gram-stain tests, and 25 for a check. All uncut tubers were surface sterilized by soaking for 3 minutes in a solution of mercuric chloride,

1:1000, and the knives used in cutting the tubers were soaked for 10 seconds in a solution of mercuric chloride, 1:500. After examination two seed pieces approximately 2 ounces in size, one designated as A and the other as B, were cut from the area nearest the stem end of each tuber. Each seed piece was then planted in a pot in the greenhouse, which was kept at a temperature of 60° F.

By using the ultraviolet light method the tubers examined were classified into three groups: (1) Those that were considered to be free from ring rot, (2) those that were thought to be infected with ring rot, and (3) those that seemed doubtful because of flourescence somewhat different from that in the second group.

The gram-stain test was made according to the method outlined by Savile and Racicot[1], but modified by taking the sample around the entire vascular ring.

Approximately 1 month after planting, examinations were made for plant emergence. A few of the plants did not emerge because the seed piece rotted In no case, however, was bacterial ring rot found in the non-sprouting seed pieces in a group determined as disease-free by either method. All the plants were allowed to grow to maturity, but before this time ring-rot symptoms developed in most of the plants in the presumably infected groups. Just prior to harvesting, gram-stain tests were made of every stem from the plants in each group, but no stem infection was found in either one of the two groups considered to be free from ring rot.

After harvest, every tuber grown in the pots and many of the old seed pieces remaining in good condition were carefully examined by the gram-stain method for the presence of bacterial ring rot. Again, none of the disease was found in the groups selected as healthy by either the ultraviolet-light examinations or the gram-stain tests. Most of the old seed pieces from the diseased groups were too badly decomposed to permit further examination. The results obtained indicate that (1) the accuracy of the ultraviolet-light method was just as effective as the gram-stain method, (2) the ultraviolet light examinations were made in less than one-tenth of the time necessary for the gram-stain tests, and (3) the ultraviolet-light method had additional value in detecting and thus reducing the incidence of other vascular disorders.

Tests with fluorescent light in Colorado confirmed the fact that the light is more effective in detecting ring-rot symptoms at 40° F. than at 70°. Of a lot of 534 tubers known to contain 29 per cent ring

[1]Savile, D. B. O., and Racicot, H. N. 1937. Bacterial wilt and rot of potatoes. Sci. Agr. 17: 518-522.

rot, tubers classified as healthy on the basis of light examination at 70° F. were rechecked by microscopic examinations using the gram-stain, and by this method 3.4 per cent infected tubers were found. Another lot of 527 tubers containing 24 per cent ring rot was examined by the light at 40° F. Those classified as healthy were again examined by the gram-stain method and were found to contain 0.44 per cent ring rot.

In Colorado several species of insects were tested as possible carriers of ring rot. It was found that several of these are capable of carrying the ring-rot organism from the foliage of infected plants to the foliage of healthy plants. This was determined by petiole smears. Whether or not the migration of the bacteria in the plants is rapid enough to infect the tubers is still under study.

Summary

The results in these reports show that potato ring-rot does not spread from hill to hill or from row to row.

The causal organism, *Phytomonas sepedonica,* may overwinter in infected tubers in the soil, but experiments on the overwintering of the organism in the soil itself gave negative results in practically all tests. The exception was a test in Wyoming, which indicated that under some conditions the organism may overwinter in the soil, but in relatively small numbers.

As in the past, mercuric chloride and acidulated mercuric chloride solutions were highly effective, and iodine was almost as effective in disinfecting cutting knives, whereas practically all other chemicals tested gave unsatisfactory results. Injury to the seed pieces due to these treatments varied in different areas from serious to practically none. Boiling water in exposures of 5, 10, and 15 seconds gave good results and offers possibilities as an aid in the control of ring-rot.

Corrosive sublimate, 1:500, gave some of the best results in controlling the spread of ring-rot between healthy and infected seed pieces.

Acidulated mercuric chloride and Cinnex Special also gave very satisfactory control. Injury to seed pieces due to those treatments varied in different areas from serious to practically no injury at all.

Many disinfectants when used as a spray gave highly satisfactory results in disinfecting pieces of wood contaminated with the ring-rot organism. Fumes of chemicals tested were in practically all cases ineffective.

The ultraviolet-light method for the detection of affected tubers continues to give satisfactory results, but this process must be operated under proper conditions.

SAMPLE SIZE AND RELIABILITY

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Potato tubers are planted by some agencies in the greenhouse and in the South in order to determine as early as possible how much virus disease is present in the seed stocks represented by the tubers. The larger the number of tubers representing a given seed stock, the more reliably will they forecast the amount of disease to be found later in the field. However, the cost of planting a number of samples will be greater. Every agency must decide for itself what size sample will offer the best compromise with respect to reliability and expense. The decision may be made easier by the availability of a table showing the minimum sample size that may be expected to give reliability of a certain degree.

The table may be used as follows. Suppose that one wishes to have enough tubers so that with 3 per cent disease present in the sample it is certain that the percentage in the stock is between 2 and 4 per cent. The number given in the table for 3 per cent with a 1.0 per cent range of reliability is 2735.

To verify, we may use the formula that per cent diseased $\pm$ its P.E. $= 100\ p \pm 67.449\sqrt{dh/n}$, wherein d is the fraction diseased expressed as a decimal, h is the fraction healthy expressed as a decimal, and n is the number of tubers (*1*, p. 208). We then have:

$$2.00 \pm \text{P.E.} = 100 \times .02 \pm 67.449\sqrt{.02 \times .98/2735} = 2.00 \pm 0.18.$$
$$3.00 \pm \text{P.E.} = 100 \times .03 \pm 67.449\sqrt{.03 \times 97/\ 2735} = 3.00 \pm 0.22.$$
$$4.00 \pm \text{P.E.} = 100 \times .04 \pm 67.449\sqrt{.04 \times 96/2735} = 4.00 \pm 0.25.$$

The difference here between 2.00 and 3.00 with its probable error, which is the square root of the sum of the squares of the probable errors 0.18 and 0.22 (*2*, p. 243, and *3*, p. 228), is 1.00 ± 0.28. The difference between 3.00 and 4.00 similarly is 1.00 ± 0.33. The ratio of 1.00 to .28 and .33 is respectively 3.6 and 3.0, averaging 3.3 which gives odds of 37.40 to 1 (*2*, Table VII, p. 479). This is somewhat over the odds of 30 to 1 that are generally accepted as indicating significance (*2*, p. 237) and means that a reading of 3.0 per cent from a sample of 2738 tubers practically assures one that the stock has between 2.0 and 4.0 per

Range of Reliability Per Cent	P. E. of Mean Per Cent	Number of Tubers Needed for Reliability at a Reading of:								
		2 Per Cent	3 Per Cent	4 Per Cent	5 Per Cent	6 Per Cent	7 Per Cent	8 Per Cent	9 Per Cent	10 Per Cent
±0.50	±0.11	7369	10941	14438	17866	21206	24477	27673	30794	33839
±1.00	±0.22	1842	2735	3610	4465	5302	6119	6918	7698	8460
±2.00	±0.44			902	1116	1325	1530	1730	1025	2115
±3.00	±0.66							769	855	940
±4.00	±0.88								481	529
±5.00	±1.10									338

cent. That is, with odds of about 37 to 1, only one in 38 samples would be so misrepresentative that the sampled stock would be found to be outside the limits 2.0 to 4.0 if read at least as carefully.

As another example, take the number given in the table for 10 per cent with a 4 per cent range of reliability, 529. Verifying as above we have:

$$6.0 \pm \text{P.E.} = 100 \times .06 \pm 67.449\sqrt{.06 \times .94/529} = 6.00 \pm 0.69.$$
$$10.0 \pm \text{P.E.} = 100 \times .10 \pm 67.449\sqrt{.10 \times .90/529} = 10.00 \pm 0.88.$$
$$14.0 \pm \text{P.E.} = 100 \times .14 \pm 67.449\sqrt{.14 \times .86/529} = 14.00 \pm 1.02.$$

The difference between 6.00 and 10.00 with its probable error is 4.00 ± 1.12. The difference between 10.00 and 14.00 with its probable error is 4.00 ± 1.35. The ratio of 4.00 to 1.12 and 1.35 is respectively 3.6 and 3.0 averaging 3.3 which gives odds of 37.40 to 1. Therefore with a sample of 529 tubers giving a reading of 10 per cent, one can be practically sure that the stock represented will give a reading between 6.00 and 14.00 per cent.

The various numbers in the table which represent sample size are approximate and were determined by using that part of the formula given above which pertains to the P.E., with n unknown and using the probable error in the second column of the table, which corresponds to the desired range of reliability. For example, if the number were sought for a range of reliability of $\pm$ 2.00 at 7 per cent, the P.E. desired would be 0.44 per cent. Substituting in the formula, we have

$$0.44 \text{ per cent} = 67{,}449\sqrt{dh/n.}$$

As pointed out by Hartzell (*1*, p. 208), , $n = (67.449)^2\, dh/(\text{P.E.})^2$. Shortening the 67.449 to 67.45 and solving for n, we have: $n = (67.45)^2 \times 0.07 \times 0.93/0.44^2 = 1530$.

Using this method, the table may be extended so that it may be applied to the data from any experiment.

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THE SEVERITY OF POTATO SCAB IN RELATION TO THE USE OF NEUTRALIZED AND ONE-THIRD NEUTRALIZED FERTILIZERS

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Since the introduction of non-acid fertilizers there has been concern on the part of some farmers and agricultural workers that the limestone added as a filler to these fertilizers would induce scab on potatoes. In 1939 Cook and Nugent (1) presented preliminary data which showed that the occurrence and severity of scab are influenced by the type of fertilizer only to the extent that the fertilizer affects the soil reaction. These conclusions have been confirmed by further experiments during the last three years, the results of which will be published in the near future.

Additional information on the influence of fertilizer reaction and lime content on scab was also obtained in 1941 from an experimental plot that had been treated with neutralized and ⅓ neutralized fertilizers since 1935. This experiment was originally conducted by

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Houghland and Strong (2) in a study of the nitrogen source, magnesium source, and reaction of potato fertilizers. They noted that scab occurred in 1938 on the potatoes in two of the replications receiving neutralized fertilizer and in five of them during 1939, but that no scab occurred in those receiving ⅓ neutralized fertilizer. In the five years that the experiment had been conducted, the soil reaction where ⅓ neutralized fertilizer was used had been reduced from an average reaction of approximately pH 5.0 to about pH 4.5, but where neutralized fertilizer was used little change had taken place from the original soil reaction of pH 5.0.

The experiment was continued by the writers in 1941 for the purpose of determining whether the lime in neutralized fertilizer was the direct cause of scab development or whether it merely served to maintain the soil reaction at a favorable level.

The experiment consisted of eight fertilizer treatments replicated six times. Each replication consisted of four rows 110 feet long. All the treatments were 6-6-5 fertilizer mixtures formulated as indicated in table 1 and applied at the rate of 2000 pounds per acre. The fertilizer

TABLE 1.—*Formulation of 6-6-5 fertilizer mixtures*

Treatment No.	Inorganic-organic Nitrogen Ratio	Source of Magnesium	Reactions*
1	80:20	Kieserite	⅓ neutral
2	80:20	Dolomitic limestone	Neutral
3	80:20	Kieserite	Neutral
4	80:20	Dolomitic limestone	⅓ neutral
5	60:40	Kieserite	⅓ neutral
6	60:40	Dolomitic limestone	Neutral
7	60:40	Kieserite	Neutral
8	60:40	Dolomitic limestone	⅓ neutral

*Reaction refers to the acid-forming or non-acid-forming properties of the fertilizer when applied to the soil as determined by the method of Pierre (Ind. & Eng. Chem. Anal. Ed. 5:229-234. 1933.)

treatments were applied to the same plots for 7 years, thus permitting a study of the cumulative effects of the treatments on scab. Before neutralizing, the fertilizer with 80-20 inorganic organic nitrogen ratio had an equivalent acidity of 362 pounds $CaCo_3$ (calcium carbonate) per ton whereas, the 60-40 fertilizer had an equivalent acidity of 296 pounds of $CaCO_3$ per ton. The ⅓ neutralized fertilizers contained only ⅓ of these amounts of limestone in each case.

In order to insure the presence of the scab organism in all of the replications, the seed planted in one of the center rows of each replica-

tion was inoculated just before planting by dipping it in a suspension of the scab organism. The scab data presented in this paper were obtained from potatoes with a minimum diameter of 1⅞ inches harvested from the inoculated row. The scabbed potatoes were separated from the healthy ones and the percentage of these by weight was recorded. A composite soil sample was taken from the inoculated row of each replication and the pH determined. These data are summarized in table 2.

TABLE 2.—*Effect of fertilizer on soil reaction and percentage of scabbed potatoes*

Treatment No.	Fertilizer Reaction	Average of Six Replications	
		Percentage Scabbed	Soil Reaction*
		Per Cent	pH
1	⅓ neutral	6.78	5.34
2	Neutral	42.08	5.63
3	Neutral	56.46	5.51
4	⅓ neutral	8.05	5.13
5	⅓ neutral	15.31	5.29
6	Neutral	40.67	5.57
7	Neutral	47.44	5.67
8	⅓ neutral	11.98	5.28

*Average C_H converted to pH.

It will be noted that the average soil reaction is less acid and there is more scab in the plots receiving the neutralized fertilizer than in those receiving the ⅓ neutralized fertilizer.

The data were analyzed as a factorial experiment following the method used by Houghland and Strong (2, table 3) to see if there actually was a significant difference in the amount of scab on potatoes from the plots receiving the neutralized and ⅓ neutralized fertilizers. All the data for percentages of scab were transformed to degrees of an angle before being analyzed and the requirements for significance in table 3, 3A, 4, and 5 are given in degrees of an angle. The analysis, which is given in table 3, shows that the data for scab in relation to fertilizer reaction are significant at the 1 per cent point. Table 3A shows that there is significantly more scab in the plots receiving neutralized fertilizer than in those receiving ⅓ neutralized fertilizer when the data are analyzed on the basis of fertilizer reaction alone.

TABLE 3.—*Analysis of data for percentage of scabbed No. 1 potatoes*

	D.F.	Sums-sqs.	Variance	F
Replications	5	4580.73	916.15	5.89
Treatments	7	8248.12	1178.30	75.76**
N source	1	7.17	7.17	.05
Mg. source	1	137.36	137.36	.88
Fert. reaction	1	7397.84	7397.84	45.56**
Interactions				
1st order				
N x Mg	1	3.54	3.54	.02
N x Fert. react.	1	544.34	544.34	3.50
Mg. x Fert. react.	1	146.73	146.73	.94
2nd order				
N x Mg x Fert. react.	1	11.14	11.14	.07
Error	35	5443.46	155.53	
Total	47	18272.31		

**Significant at 1 per cent.

Although the analysis used in table 3A shows a very definite correlation between the amount of scab and the reaction of the fertilizer, it does not show whether the increased amount of scab in the neutralized fertilizer plots is the direct result of the larger amount of lime that the fertilizer contained or whether it is because the amount of lime contained in the neutralized fertilizer maintained the soil reaction at a level favorable for the development of scab. The effect of continued use of neutralized, or even partially neutralized fertilizer, on the reaction of the soil and the ultimate effects on scab development are factors of considerable practical importance to potato growers.

In order to study this relationship between the amount of scab obtained and the soil reaction, the data from all the fertilizer treatments, without regard for their degree of neutralization, were divided into two groups on the basis of the resultant soil reaction and analyzed.

TABLE 3A.—*Amount of scab in relation to fertilizer reaction*

Kind of Fertilizer	Ave. Amount of Scab
Neutralized	42.25
⅓ neutralized	17.42
Difference	24.83
Difference required for significance	7.31

TABLE 4.—*Amount of scab on potatoes in relation to soil reaction*
(Combined data from neutralized and ⅓ neutralized fertilizer plots)

Soil Reaction (pH) of Groups		Number of Samples	Ave. Amt. of Scab	Diff. between Groups	Diff. Req. for Sign. (1 per cent point)
Average	Range				
4.99	4.7 - 5.1	12	13.34		
5.55	5.2 - 6.0	36	35.33	21.99**	15.6

**Significant at 1 per cent point.

The results (table 4) show that there was significantly more scab on potatoes grown in the soil with a pH of 5.2 to 6.0 than on those grown at a pH of 4.7 to 5.1.

The same method of analysis was applied separately to the data from the neutralized and ⅓ neutralized fertilizer plots to see if the same correlation between scab and soil reaction would be found when all

TABLE 5.—*Amount of scab on potatoes in relation to soil reaction*

Data from plots receiving neutralized fertilizer.

Soil Reaction (pH) of Groups		Number of Samples	Ave. Amt. of Scab	Diff. between Groups	Diff. Req. for Sign.
Average	Range				
5.05	5.0 - 5.1	3	16.79		
5.64	5.25 - 6.0	21	45.89	29.13*	22.36

(Data from plots receiving ⅓ neutralized fertilizer.)

Soil Reaction (pH) of Groups		Number of Samples	Ave. Amt. of Scab	Diff. between Groups	Diff. Req. for Sign.
Average	Range				
4.97	4.7 - 5.1	9	12.19		
5.39	5.2 - 5.75	15	20.54	8.35*	7.36

*Significant at 5 per cent point.

of the plots had received either one or the other kind of fertilizer. The data for each kind of fertilizer were significant at the 5 per cent point when divided into pH groups as was done with the combined data in table 4. The range of the pH groups differed somewhat with each kind of fertilizer. It did not extend as low in samples from the neutralized fertilizer group or as high in the samples from the ⅓ neutralized fertilizer groups. The analyses are presented in table 5.

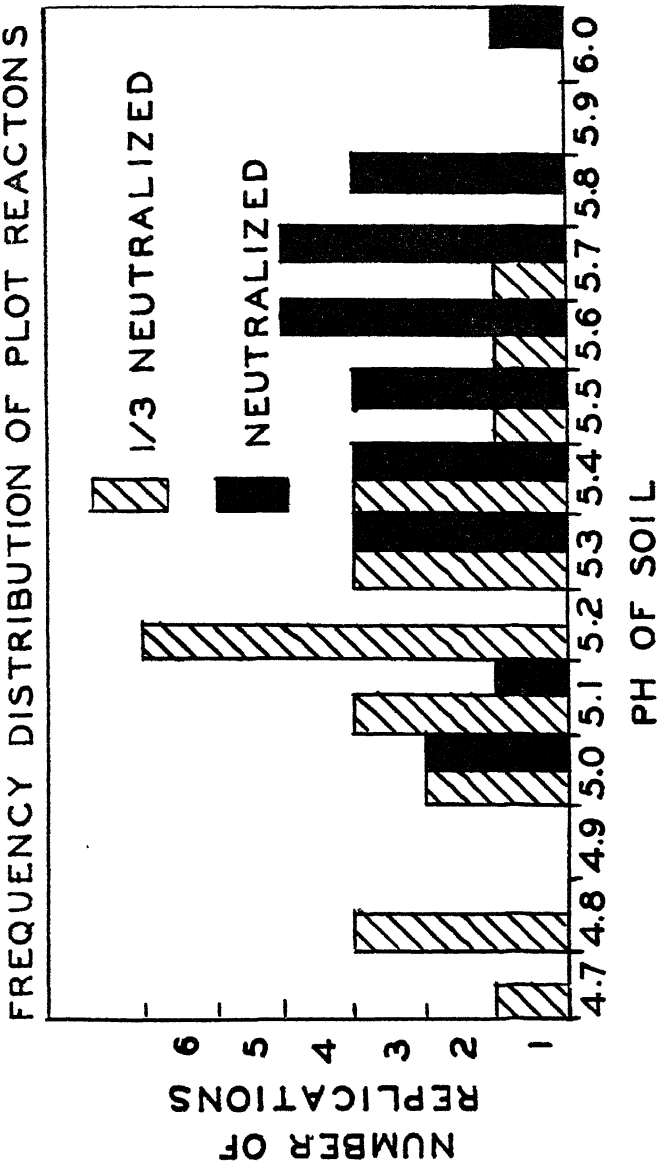
From the data in table 5 it may be seen that the amount of scab on the plots receiving either neutralized or ⅓ neutralized fertilizer is correlated with the soil reaction. The average amount of scab in the low pH group from the neutralized fertilizer plots was slightly larger than in the corresponding group from the ⅓ neutralized fertilizer plots (12.19 and 16.79), but even this slight increase was correlated with a slightly higher average soil reaction (pH 4.97 and pH 5.05 respectively). The average amount of scab in the high pH group was considerably larger for the neutralized fertilizer plots than for the ⅓ neutralized fertilizer plots (20.54 and 45.89) but this increase also was associated with a correspondingly higher average soil reaction (pH 5.2 and pH 5.64 respectively).

If the data for the average amount of scab from table 5 is arranged in consecutive order as is done in table 6, it will be seen that it is also in order according to the average soil reaction.

An explanation for the significantly larger amounts of scab in the potatoes from the neutralized fertilizer plots as shown by the analysis in table 3A may be seen by referring to the graph in figure 1 which shows that most of the soil samples from the neutralized fertilizer plots have reactions above pH 5.2 whereas most of those from the ⅓ neutralized plots have reactions below pH 5.4. The average soil reaction for the neutralized and ⅓ neutralized fertilizer plots was pH 5.59 and pH 5.28, respectively.

TABLE 6.—*Data from table 5 arranged in order according to the average amount of scab and the soil reaction*

Kind of Fertilizer	Group	Average Soil Reaction (pH)	Average Amount of Scab
⅓ neutralized	low pH	4.97	12.19
Neutralized	low pH	5.05	16.79
⅓ neutralized	high pH	5.39	20.54
Neutralized	high pH	5.64	45.89


FREQUENCY DISTRIBUTION OF PLOT REACTONS
1/3 NEUTRALIZED
NEUTRALIZED
NUMBER OF REPLICATIONS
1
2
3
4
5
6
4.7
4.8
4.9
5.0
5.1
5.2
5.3
5.4
5.5
5.6
5.7
5.8
5.9
6.0
PH OF SOIL

CONCLUSIONS

These data show that the neutralized and ⅓ neutralized fertilizers used continuously for 7 years ultimately affected the occurrence and amount of potato scab principally through their effect on the degree of acidity of the soil.

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DIAGNOSIS OF THE BACTERIAL RING ROT OF THE POTATO

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Ever since the bacterial ring rot of potatoes, caused by *Corynebacterium sepedonicum,* has become of economic importance in America, considerable difficulty appears to have been encountered in diagnosing the disease. All new plant diseases, no doubt, make one a little uncertain at first. With the ring rot, however, the difficulty of diagnosing the disease still appears to remain. This difficulty, it is felt, may be attributed to several reasons. In the first place it is frequently confused with other diseases. The early descriptions of the symptoms of the ring rot, before the causal agent was known, plainly show this confusion. At times the description resembles the brown rot of the South caused by *Phytomonas solanacearum,* whereas at other times it might be a Fusarial wilt and tuber rot. Also the tuber symptoms as set forth in the early literature could be mistaken for the soft rots caused by *Erwinia carotovora* or *E. phytophthora.* It is true the bacterial ring rot has similarities with all these diseases, but a careful study of the ring rot in the growing plant should eliminate the possibilities of one mistaking it in the field or bin for some other disease. The difficulty of diagnosing the disease, the writer feels, is also somewhat psychological. The ring rot is of fairly recent origin in America and all of us

are not familiar with it. It has been very severe at times, and since it is spread extensively at cutting time from a few infected tubers, a zero tolerance for it has been demanded for certified potatoes. The plant pathologist, therefore, approaches a diagnosis of the disease with some fear and misgivings. He must be sure the stock he is inspecting is free from the disease since its infectious nature allows it to spread rapidly at planting time and a few infected tubers can make certification appear ineffective. On the other hand, a conscientious inspector is loath to state that ring rot is present in a stock without being certain because the seed would be rejected from certification. The inspector, therefore, demands an absolute test of yes or no for the disease, although he would not think of demanding this for one of the older but equally destructive diseases. And it is not probable he will find such a test for the ring rot.

The above situation is somewhat different from that of an investigator who wishes to eliminate the ring rot from some special stock and can discard everything suspicious whether it is ring rot or not. He is not called upon to be positive concerning a diagnosis. Ordinarily growers will not attempt to eliminate the disease from their stock nor should they try. They will want to know, however, whether they have the ring rot so they may dispose of their present stock and obtain new seed. Determining whether ring rot is present in a carload of tubers is also another matter. If the percentage of diseased tubers is very small in such a case, it becomes rather hopeless, as would be the case with any disease.

Most plant diseases are diagnosed from their symptoms. This naturally necessitates a previous study of the disease under various environmental conditions. This, I think, is imperative with the bacterial ring rot. Reading other investigators' descriptions of infected plants or examining pictures of the disease is not sufficient, though helpful. To describe the symptoms here is scarcely worth while. Stapp (8), Eddins (2), Racicot, Savile, and Connors (6), and many others have done a good job which is available to all. The disease symptoms, however, should be studied in the infected plants. After working with potato diseases and especially bacterial ring rot for several years, J. B. Skaptason has stated to the writer that he feels he can diagnose 90 per cent or more of ring rot specimens by symptoms alone. Any inspector should be able to do this.

Doubtful cases of the disease naturally exist, as they do with all other diseases. It is only this small percentage which should cause trouble. These anomalous types are usually those of light infection

by the pathogen or of too heavy contaminations by secondary organisms. In the former cases the mottling and wilting of the above ground parts may scarcely appear, or may be masked by droughts, insects or early maturity. Light infection of tubers may appear as only a pale yellow condition of the vascular ring which color is not uncommon in healthy tubers although the texture of the diseased tissue is different. A careful inspection and a sharp eye must be used for these cases. Secondary organisms, too, may upset the disease picture especially when they are capable of producing a severe rot. Nevertheless, an examination of the entire plant should be made, if possible, and especially more than one tuber from a hill should be seen. If severely rotted tubers are received for diagnosis they should be discarded and fresh specimens demanded. In the diseased tubers, the advancing margin of the necrotic areas should be examined carefully, for here one may obtain an indication of the trouble.

Certain laboratory procedures have been put forth by various investigators as specific tests for the ring rot, or at least, aids in diagnosing the disease. A brief discussion and evaluation of the most frequently discussed methods will be given.

Iverson and Kelly (4) were the first to observe that the diseased tissues of tubers infected with the ring-rot pathogen exhibit a fluorescence when placed under ultra-violet light. They suggested this character for a diagnostic test. Although they reported that decaying tissue due to other causes also fluoresce, they are of the opinion that with some study, a difference could be seen in the type of fluorescence. Skaptason (7) demonstrated that the substance causing the fluorescence produced in tubers affected with ring rot is riboflavin and that it gives a greenish fluorescence whereas other rots show a bluish tinge. *Corynebacterium sepedonicum* produces this vitamin in culture and the fluorescence under these conditions is typical with that in the diseased tubers. This character is a help, without doubt, in diagnosing the disease but is scarcely specific since it is known that many bacteria produce riboflavin. Whether other potato pathogens produce this substance is not known, but it is possible that some of the numerous secondary organisms might. Furthermore it is not known whether other substances beside riboflavin give a green fluorescence when exposed to ultra violet light. The writer has found that this test is an aid especially in diagnosing cases of light infection, but possibly certain precautionary measures should be taken. Iverson and Kelly (4) have emphasized that the ultra-violet light examination should be made only at a temperature of 40°F. or lower since a high temperature reduces the effectiveness of the procedure.

Skaptason pointed out that riboflavin is destroyed rapidly at high temperatures, especially under ultra violet light.

Certain investigators seem to think that, if smears are made from diseased tissue and stained with the Gram strain, a positive reaction is a definite indication of the presence of *C. sepedonicum*. The writer is not of this opinion, for several reasons. First, although this pathogen is the only Gram positive organism which we have any knowledge of at present, which rots potato tubers and attacks stems, certain secondary organisms might be Gram positive. Then, too, the Gram stain is a very unreliable stain. There are many instances in literature where a bacterium has been described as Gram-positive or Gram-negative, whereas upon further study it was found that the opposite was true. One single staining procedure is scarcely sufficient to determine the Gram reaction of a bacterium. Furthermore an organism that is generally known to be Gram-positive may be Gram-negative under certain conditions.

Israilki and Artemieva (3) state that Gram test on tomatoes examined for the bacterial canker (*Corynebacterium michiganense*) were only 82 per cent correct. Iverson and Harrington (5) were able to eliminate all ring rot from tubers by both the ultra violet light test and the Gram test. Their data do not show, however, that their diagnosis was always correct since approximately 10 per cent of their tubers that were considered diseased gave rise to healthy plants.

Another stain which the writer has found helpful, but on which one should not rely too much, is the Congo red stain for demonstrating the morphology of the pathogen. *C. sepedonicum* is a small pleomorphic bacterium, smaller than the usual type of secondary organisms and considerably different in shape. It has many wedge-shaped cells, some club, and, if growing rapidly, V and L-shaped forms because of its manner of division. With a thorough study of the pathogen one becomes familiar with its appearance. Congo red being an indirect stain demonstrates these peculiarities better than one of the direct stains. The method of using Congo red has been described (1). It is possible, however, that the Gram stain also could be used for the morphological study and thus eliminate the necessity for the Congo red stain.

Tipograf (9) in Russia reports a serological method for diagnosing ring rot of potatoes. So far no method of this kind has proved practicable for determining a plant disease of either bacterial or fungous origin. The description of Tipograf's procedure in the Review of Applied Mycology does not seem reasonable, and the fact that 22 per cent of the plants that appeared to be disease-free, gave positive results

makes one suspicious of the method. Furthermore, at present, very few plant pathology divisions are equipped to carry on serological work.

Perhaps the most positive method of diagnosing a plant disease is to isolate the pathogen and inoculate healthy plants with it. If infection is obtained one feels sure of his diagnosis. In some plant diseases when there is some doubt about the trouble this test may be applied without too much difficulty. With the ring rot there are a number of difficulties. The isolation of *C. sepedonicum* is slow and tedious, even under favorable conditions. Negative results would not mean that the pathogen was not there since the growth requirements of this bacterium are very particular. Also the incubation period in the potato is of long duration. Therefore, the procedure of isolation and inoculation can scarcely be recommended except under peculiar circumstances. With this method too long a time would elapse before one could be positive of the results. With those who have worked with the pathogen in culture and are familiar with it, the inoculation experiment might not be necessary.

In conclusion it seems fair to state that if one were familiar with potato diseases and especially ring rot in the living plant, the disease in the majority of cases could be diagnosed by symptoms alone. Where there is some doubt, macroscopical examination under ultra violet light and microscopical examination for the Gram reaction and the morphology of the pathogen should enable one to reach a conclusion. Any one test is not sufficient.

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THE PERFORMANCE OF CERTAIN POTATO VARIETIES IN SOUTH CAROLINA IN 1942

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Variety tests with potatoes have been conducted at the S. C. Truck Experiment Station for a number of years to determine whether any of the newer varieties are better adapted to this area than Irish Cobbler which has been the standard variety in coastal South Carolina for many years. In 1942 the variety tests were expanded to include two outfield experiments on representative farms as well as the regular experiments on station plots. Randomized blocks were used in each experiment with 5 replications of each variety. The results obtained in 1942 agree rather closely with those of other years and are given in table 1.

The performance of Pontiac in these experiments was outstanding. This variety had given very high yields in 1941 on a number of different soil types in the Charleston area. Therefore, a fairly good yield was expected in 1942. It will be seen from table 1 that Pontiac gave a mean yield for three locations of 214.6 bags of No. 1's per acre, which was a significantly higher yield than any of the other varieties except Sequoia and Bliss Triumph. Furthermore, it ranked first in yield at each of the three different locations. Pontiac is classed as "late" in some potato-growing states, but in South Carolina it is only a few days later than Irish Cobbler and may be harvested at the same time. The tubers are red in color, fairly smooth, and make an attractive appearance.

Sequoia also produced high yields of No. 1 potatoes in 1942 but its lateness, compared with other varieties, is one factor against it. In most years it is about ten days to two weeks later than Irish Cobbler but this is partially outweighed by the fact that it consistently yields more than the earlier varieties. Some growers who plant large acreages of potatoes could afford to plant a late variety of this kind because their digging operations require a period of several weeks, but as a rule, the average grower does not want a variety any later than Irish Cobbler.

In 1942 Sequoia exhibited 3 per cent to 5 per cent sprouting of

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tubers at the time the potatoes were harvested. This was the first year that sprouting was observed and it appeared to be due to weather conditions which were conducive to sprouting and second growth. The varieties Earlaine No. 2, White Rose, and Spaulding Rose produced a large amount of second growth.

For all-around dependability Katahdin appears to be the best of the newer varieties for coastal South Carolina. It can be relied on for good yields nearly every season, and some years, especially on moist, fertile soils, it produces yields that are significantly higher than those of Irish Cobbler. In addition, it produces smooth, shallow-eyed tubers which command a premium on some markets.

Good stocks of Chippewa have given high yields of very attractive potatoes but it has been almost impossible to get seed potatoes of this variety that were not infected with leaf roll. In recent tests Chippewas from North Dakota and from Nebraska were apparently free from leaf roll and gave very satisfactory yields as shown in the table.

Interest in the variety known as White Rose was aroused a few

TABLE 1.—*Results of potato variety experiments at three locations in Charleston County, South Carolina in* 1942

No.	Variety	Source	Yields in 100 Pound Sacks of U. S. No. 1's per Acre			
			Truck Station*	Farm A*	Farm B*	Mean
1	Pontiac	Michigan	183.0	175.2	285.5	214.6
2	Sequoia	No. Carolina	167.2	135.5	276.9	193.2
3	Bliss Triumph	Maine	137.2	167.2	239.7	181.4
4	White Rose	Minnesota	151.7	147.5	224.2	174.5
5	Katahdin	Maine	147.9	163 9	202.7	171.5
6	Irish Cobbler	Maine	142.7	145.3	224.3	170.7
7	Warba	Maine	120.9	149.1	220.1	163.4
8	Earlaine No. 2	Maine	123.0	144.5	220.1	162.5
9	Chippewa	No. Dakota	130.5	139.0	196.9	155.5
10	Houma	Maine	144.2	115.2	200.7	153.4
11	Chippewa	Maine	130.0	122.4	177.3	143.2
12	Sebago	Maine	121.6	115.5	181.2	130.4
13	Spaulding Rose	Maine	115.6	123.1	145.4	128.0
14	Chippewa	Nebraska	...	...	266.8	

Difference required for significance (19:1): 33.8 sacks.

*Means of 5 replications.

years ago in the Charleston area with the result that it has been planted commercially by several growers with varying degrees of success. In replicated tests with other varieties (on average soils) it has often yielded more than Irish Cobbler but during periods of drought followed by occasional rains—conditions which occur frequently during May in this area—it tends to make a large amount of second growth, with the result that the knobby tubers are produced which fail to make the U. S. No. 1 grade. Under good soil and weather conditions very good yields of fairly smooth tubers have been made but on the whole, it appears that White Rose is not dependable enough for extensive use in this area and it cannot be recommended as long as other varieties are available.

Sebago is a variety which produces some of the smoothest, brightest tubers of any of those tested to date, but it is so late that even when dug at the end of the normal growing season it yields less than most of the other varieties. It is possible that it might be useful to those growers who want a late potato to harvest after Irish Cobbler, but it cannot be used to replace earlier varieties because of the low yields obtained.

The difficulty of getting good clean seed potatoes was emphasized again in the variety tests this season. Many of the varieties were infected with mosaic and leaf roll and one lot of Chippewa exhibited 70 per cent leaf roll. Although rolling of the leaves of Chippewa is often said to be a natural physiological condition of the variety it was found that two good stocks which came from points in Nebraska and North Dakota showed no rolling of the leaves whatever. The same Nebraska stock did not show any leaf roll last year, either. As shown by the yields obtained on Farm B (variety No. 14), Chippewas, when free from leaf roll and other diseases, is capable of producing high yields of No. 1 potatoes.

Leaf roll was a factor in reducing the yields of Irish Cobbler, Katahdin, Sebago, Houma, Earlaine No. 2, and Chippewa (Maine). Most of the other varieties were fairly free from the disease. In addition to leaf roll, Irish Cobbler and Earlaine No. 2 were infected with mosaic, and White Rose exhibited close to 100 per cent mild mosaic.

Late blight ordinarily does not appear during the spring season in South Carolina but in 1942 it appeared in late May, near the end of the season. It was found that Sebago, Sequoia, and B-5 (a Nebraska seedling) were partially resistant under the conditions which prevailed at that time.

Taking everything into consideration it appears that Irish Cob-

bler and Katahdin are the best white-skinned varieties for South Carolina although Chippewa produces very attractive tubers and may under certain conditions produce high yeilds. Irish Cobbler is a dependable producer, even under unfavorable growing conditions, and it usually makes yields that are as high as, if not higher than, those of the other varieties commonly grown in this area.

Pontiac is the most prolific of the red-skinned varieties in the coastal area of South Carolina and it usually produces smoother tubers than Bliss Triumph or Red Warba. It is later than the other red-skinned varieties, however, and is usually harvested no earlier than Irish Cobbler. Bliss Triumph should be planted for earliest red potatoes.

VALUE OF THE ALABAMA POTATO SEED-TESTING PROGRAM

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Before attempting to discuss the benefits which have been derived from the Alabama seed-testing program, a classification of seed trials and a brief outline of the Alabama seed-testing program will be given.

SEED TRIALS CLASSIFIED

Southern tests of seed potatoes differ in their experimental design, in their objectives, and in the states which sponsor them.

In design southern field tests may range from simple planting of seed lots, lines, or strains for disease readings only to more complicated tests designed to study disease, general behavior, and performance of different lots under southern conditions.

These trials may be sponsored by and conducted for the benefit of either the growers in the seed-producing states or in the seed-consuming states. The benefits may be direct in some cases and quite indirect in others. Either group may benefit materially by tests conducted by the other group.

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Objectives and Provisions of the Alabama Seed-Testing Program

The Alabama seed trials* are sponsored for the benefit of Alabama growers. It is known, however, that growers in other states have benefited in many respects as much as have local growers.

Alabama is more than glad that a program designed for its own growers may be of value to growers of other states,—especially those in the business of producing seed used in Alabama, but in the final analysis the Alabama seed-testing program is designed specifically to give Alabama potato growers better seed.

It should be remembered that the South Alabama potato growers, for whose benefit the program is conducted, produce potatoes almost entirely for table stock. They are not interested in the production of seed. Alabama growers are, therefore, interested primarily in high yields of uniform, high-quality, table stock. Good seed to an Alabama grower is seed which gives him these three things. Diseases, so important to those in the business of producing seed potatoes year after year, are of interest to Alabama growers only as they affect either the yield or the quality of the immediate crop for table use.

Briefly stated, the Alabama regulations require that a given seed lot, before it is approved for planting in Alabama, in addition to meeting all the certification requirements of the state where it originates, must be tested in Alabama the year prior to approval and when tested must not exceed certain disease limits and must yield at least 75 per cent of the yield of the 10 highest yielding lots on test.

The yield requirement in the Alabama program is the one feature so different from any other state. Alabama's program does not overlook disease. Disease, however, is considered as only one of many factors and not as the sole factor determining the desirability of seed for planting purposes.

Results of Alabama Trials

The Alabama seed trials have proved beyond any reasonable doubt that great differences are obtained in the yields of potatoes from different seed lots even in potatoes of the same variety and strain coming from the same state and certified under the same regulations. In experimental tests[1] in South Alabama differences in yields of different seed lots of 50 and 100 bushels per acre have been common; differences of

*The Alabama trials are conducted jointly by the Department of Agriculture, the Alabama Extension Service, and the Alabama Agricultural Experiment Station.

100 to 150 bushels, frequent; and differences of 200 to 250 bushels, occasional.

That these differences are to be found and that they are common cannot be denied. Differences of opinion exist regarding the cause of these yield variations and the practical significance in predicting the value of seed lots when they are planted commercially one year after the tests, but that different seeds lots of identical strains produce different yields in the south can no longer be doubted.

Causes for Yield Differences

That diseases are a factor in poor yields and that some of the yield differences are caused by diseases are certain. Poor stands and weak plants resulting from disease are definitely the cause of low yields in a large percentage of cases. That diseases are not the only cause of low yields or differences in yield of different seed lots is equally certain.

Some idea of the relative importance of disease and factors other than disease which affect low yields, is given in a statement made in an earlier report on the Alabama tests[1] which is quoted:

> "In 1936 there were in the Alabama field trials 172 lots of potatoes certified according to the requirements of the seed-producing states. Of this number 75 failed to qualify for certification in Alabama. In 1937, of the 138 lots of potatoes on trial, 62 failed to qualify; in 1938, of 262 lots on trial, 102 failed to qualify. Yields below the requirements were responsible for 14 rejections in 1936; 42 in 1937; and 53 rejections in 1938. There were 12 lots in 1936; 9 in 1937; and 15 in 1938 that failed to qualify both because of low yields and excessive amounts of disease. Diseases in excess of the tolerance limits were responsible for the other rejections."

Differences in strains would naturally account for certain differences in yield and general behavior where seed lots happen to represent different strains. The differences in yield referred to often occur, however, within the same strain and represent something more than inherent or genetic differences among strains.

Of the other factors likely to be important it would seem certain that physiological factors play an important part. The potato tuber is a sensitive structure. Its behavior, when planted, is affected in a major respect by its physiological condition at the time, especially by the rest period. A large number of factors, such as seasonal conditions during the growing period, maturity of tubers at harvest time, storage temperature, storage humidity, length of storage and changes in stor-

age conditions, are known to play an important part in the length of the rest period of tubers. Prompt sprouting and normal behavior of tubers after sprouting are factors affecting yield.

Recognition of the fact that factors other than disease may be responsible for low yields has led to the formulation by Alabama of a fundamental principle which enlarges the original concept of the function of certification. This enlarged concept would define as the purpose of a certification program the production of the best seed possible for the purpose grown. Since good seed potatoes for Alabama are those which produce high yields of uniform, high-quality, market potatoes, then any factor which affects yields should be considered in a certification program. Since physiological factors affect the behavior of tubers and the resulting yields, then these factors must be considered in a certification program which attempts to provide the south with good seed.

Value of the Alabama Seed-Testing Program

Some of the values or benefits which might be attributed to the Alabama seed-testing or certification program are direct, others indirect; some values accrue to the Alabama potato growers, others to the seed producers; some are definite and without question; others are questioned naturally by workers in other states as well as by workers in Alabama.

One important benefit of the Alabama seed-testing program has been the development of a keener interest in good seed and fuller recognition of the great differences which exist in different lots of certified seed. The fact that the Alabama tests have shown without reasonable doubt that large yield differences are obtained from different seed lots has greatly impressed the users of seed in Alabama and the producers of seed in other states. The fact that such differences do occur, has assigned to good seed sources an importance not before fully realized. This is entirely beside the question of the adequacy of the Alabama tests to predict with certainty the value of seed planted commercially in a given year on a basis of the experimental tests made one year earlier. As here stated, this benefit refers only to differences found between seed lots and the consequent effect of this knowledge on growers.

A second value of the trial has been to cause seed growers and certification officials in seed producing states to recognize that potato growers as well as seed producers have something at stake in good seed; that there is more in good seed than mere absence of disease; that the requirements of good seed for one group may not be identical with

the requirements of good seed for another; that good seed to southern growers means the ability of seed to produce high yields of uniform, high-quality potatoes in the south, and that this fact must be taken into account by seed producers in their seed programs.

A third value of the Alabama tests has been to show that factors other than disease are of major importance in determining good seed for southern planting. In addition to proving the point, the Alabama program has been instrumental in inducing growers and certification authorities of seed-producing states to recognize the fact in a way which has resulted in action programs of their own designed to produce better seed for southern planting.

Realizing the influence of physiological factors on the suitability of seed for planting in southern states, one seed-producing state in particular has set about to study some of these factors and to determine their relative importance. Cooperative experiments between this state and Alabama have shown that pronounced differences in yields have been obtained from identical strains of Triumph potatoes where the seed was grown on plots having different cultural histories. Likewise, cooperative studies designed to show the effects of storage methods on performance of seed in the south have given information which has led to changes in storage recommendations in at least one of the seed-producing states.

The benefits of such constructive studies to growers in both the seed-producing and seed-using states are quite obvious. Changes in cultural, harvesting, and storage practices in seed-producing states which give Alabama and other southern states better seed benefit southern growers and also strengthen the competitive position of the state which produces such seed.

That some seed-producing states are now recognizing the influence of physiological factors on the production of good seed and are modifying their programs to produce such seed would suggest that they are beginning to accept the broader concept of the function of certification to include all factors which affect the yield and market quality of the next crop from the seed certified.

A portion of a letter received from Professor H. O. Werner of Nebraska expressing his thoughts along this line will bear quoting:

> " . . . one important indirect benefit of the trials as conducted by you was your discovery that factors other than disease content are of great importance with seed potatoes. You were not able, from your trials, to determine which factors were causing high or low yields but you did point out that some other factors were present and that it was necessary to go further than merely certifying with regard

> to disease freedom. These findings and your persistence with regard to them are the underlying reasons for our undertaking our extensive investigations to determine the effect of storage conditions and degree of maturity of potatoes upon the seed value. I think our results of last year indicate quite definitely that storage is a very important factor and that by altering the storage we can greatly alter the rate and uniformity of sprouting of a lot of seed potatoes. Quite likely further studies will need to be made with regard to the effect of methods of shipping and possibly methods of handling the potatoes after they arrive in the south."

It is indeed a fortunate and a healthy situation when a seed-producing state, and a seed-consuming state, can unite their efforts to the end of investigating the factors which determine good seed. Growers in both states stand to gain; the one by knowing how better seed can be produced, the other by having available better seed to plant.

Another specific value of the Alabama seed trials to seed producers has been the use of the early disease readings in Alabama by certificational officials of the seed-producing states to prevent growers from planting stock which would have been later rejected if planted.

Furthermore, certain diseases are best detected when grown under southern conditions. In fact some diseases or conditions would be overlooked if it were not for planting under southern conditions. Again a statement from Professor Werner covers rather clearly the value of southern seed trials in the detection of disease:

> "A comparative trial of a number of lots of potatoes permits southern and also northern workers to make a general survey of the presence of diseases that may not be serious in the north but which may be carried in their seed stocks. Very little progress would have been made years ago in controlling mosaic if southern test plats had not been available for guidance and check purposes. The southern plats are also of value in connection with such diseases as haywire which is quite serious in the south but which is not so easily detected in the northern fields. The experience of a few years ago in connection with such things as hair sprout was of some value in warning northern growers of a possible serious condition in their seed stocks. These tests also enable all parties concerned to get some idea concerning the ring rot situation provided proper methods are used to prevent the spread of the disease from one lot to the other."

The values or benefits which have been discussed so far are those that probably all would recognize and admit. There is one other value on which there is less agreement. This concerns the value of the Alabama seed trials in determining the suitability of specific seed lots for

commercial planting the following year. No group is more ready than the Alabama group to agree that such a test is not infallible. It is recognized that disease readings for one year cannot unerringly reflect the disease condition one year later in commercial seed lots. There may be a large increase in the amount of disease in a given lot of seed in the producing state the same year as the test is made in Alabama Likewise, since physiological factors affect yields so greatly and since growing conditions, tuber maturity, storage conditions, etc., may be quite different one year from another, it could not be supposed that a given seed lot would behave in the same way another year; however, it is remarkable how consistently some of the same lots have led in yield each year. This may be because of superior strains, less disease, better handling methods or to all three. The Alabama grower, however, is less concerned with the reasons for high yields than with the fact of high yields and good potatoes; therefore, when he chooses his seed on a basis of past performance in the seed trials he is in effect gambling on favorable odds—namely, he is gambling on the odds that seed lots which have yielded high in past years will most likely produce high yields another year.

If the critics of this feature of the Alabama program should find themselves in the position of the Alabama potato grower, they most likely would also choose their seed from the leaders in the trials. From the Alabama growers' standpoint this shows good judgment, although in fairness to all it would have to be admitted from a standpoint of the growers in seed-producing states that some cases of individual discrimination have developed. In its final analysis the problem reduces itself to a simple question as to whether the Alabama program is designed primarily to serve Alabama growers or seed growers in other states. Naturally the Alabama program is designed primarily to benefit Alabama growers, although every reasonable effort has been made to promote those features of the program that provide good seed to Alabama growers without injury to the growers in seed-producing states.

There are two additional benefits that must not be overlooked. One is the value of personal acquaintances which have developed between growers and certification officials of the seed-producing and seed-consuming states as a result of the Alabama program. This has meant a better understanding between the two groups. The other is the personal responsibility and the pride that the individual grower feels in his own seed stock when he knows it is under close observation. In a recent visit to the Alabama trial plots of growers from a seed-producing

state, the keen interest shown by each grower in his own seed lot, and the comparisons he made between his own seed lot and other lots, left little doubt that growers would return home more determined to produce seed which would compare with the best in the Alabama trials. It means something to Alabama growers to know that seed producers are competing with one another in trying to deliver seed which produces well in performance tests in Alabama.

Measure of the Benefits

A certain measure of the benefits to Alabama for the program it has supported, is gained by a few statements: (1) The county agent in Baldwin County, where 80 per cent of Alabama's commercial crop originates, states that better seed has been responsible for a 25 per cent increase in the yield of potatoes in his county; (2) Fairhope, Alabama, at which place the Alabama seed trials are conducted, has become the Mecca of seed certification officials of states producing seed for southern plantings; (3) at one time Alabama was the "dumping ground" for seed which other states had rejected, but today Alabama growers are getting as good seed as is produced in America; (4) while the three principal states competing with Alabama fresh potatoes increased their commercial acreage during the 3-year period, 1937-'39 inclusive, only 14 per cent over the average for the preceding 10-year period, 1928-1937, Alabama increased its acreage 75 per cent and in 1941 had an acreage 107 per cent higher than the 10-year period.

These facts are sufficiently convincing to Alabama to make her feel that the program is of great value to her growers and the cost of the program is justified.

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TUBER-LINE SEED PLOTS

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An effort was begun in Maine, about fifteen years ago, to develop sizable healthy Green Mountain seed stocks by multiplying tuber-lines in an isolated location. (A tuber-line is a stock or clone of potatoes known to have been recently increased from one original tuber or part of a tuber). It was found possible to increase some tuber-lines up to an acre apiece before they were entered by virus diseases such as mild mosaic, rugose mosaic, leaf roll or spindle tuber. In order to reach larger acreages in a healthy condition, it was necessary to use an aster cloth cage (1) under which enough seed was grown to plant several acres in the open.

Since tuber-line stocks had become somewhat diseased in several apparently well isolated seed plots, it seemed desirable to plant cage-multiplied tuber-line stock in a number of locations to secure some information as to what conditions favored the entrance of virus diseases into healthy seed stocks. Also, since absolutely healthy Green Mountain seed stocks had been nonexistent because of the universal presence of at least mild mosaic in this variety, this was the first chance to learn how much virus disease would enter disease-free seed plots.

From 1933 to 1938, 114 tuber-line seed plots were grown on 74 different Maine farms with a follow-up inspection made the following year in each instance to ascertain the kind and extent of movement of virus disease into such seed stock. (2). The presence of one virus

disease did not prevent the continued use of a farmer's seed stock for the study of other virus diseases. Any virus disease present was rogued out, and in such an instance the absence of that disease the next year indicated that roguing had prevented spread within the plot and that also there had been no virus movement into the seed stock. Of course, if a virus disease was rogued out and was again present in the replanted stock the next year, it was impossible to say how much of this disease in the replanted stock was caused by spreading which occurred within the plot in spite of the roguing and how much was due to virus movement into the plot from outside.

Mosaic (mostly mild) came into 43 mosaic-free plots and did not enter 40 plots that were mosaic-free or rogued for mosaic. Leaf-roll came into 17 leaf roll-free plots and did not enter 22 plots that were leaf roll-free or rogued for leaf roll. Therefore there was at least about an even chance of these diseases entering a plot from outside. The plots studied were grown by farmers who were mostly anxious to use the plots as sources of good seed. It may be inferred that in seed plots in general and in fields grown to be certified there is usually some entrance of disease from outside.

Effect of Region, Earliness, and Isolation

The 74 farms where the 114 seed plots were grown were distributed in eight counties in the farming belt from the southwestern corner to the northeastern corner of the State. The further the seed plot was located toward the northeast, the less chance there was to get a low mosaic reading and the greater the chance to get a low leaf roll reading in the replanted seed stock. In accordance with this rule, Aroostook seed plots were usually less successful as to mosaic control, and more successful as to leaf roll control than were plots located south and southwest of Aroostook.

In each season the seed plots were classified as well as possible according to their earliness with respect to planting, roguing, and plant development. Plots were not necessarily planted earlier in southwestern Maine, since there is a later fall there which some farmers depended upon to permit later planting without loss from fall frost. Plots were rogued as soon as the plants were large enough. In several years the early plots produced seed stocks with significantly less mosaic than the medium or late plots, and in several years seed plots classified as early or medium produced seed stocks with significantly less leaf roll than did later plots. Therefore there was a general trend

in favor of greater success as the plot was earlier in planting and in the development of the plants.

The seed plots ranged in size from one-twelfth acre to nine acres, averaging about 1.4 acres. Generally the larger the seed plot, the less mosaic there was in the replanted seed stock. However, the correlation was never significant, was not consistent for leaf roll, and for mosaic might have been due more or less to small size of plot being correlated with higher disease percentage. At any rate, there was no indication that the seed plot was more successful as it was smaller.

When the seed plots were rogued, an examination of the nearest other potato fields was made unless they were more than one-half a mile distant, and even then sometimes they were examined. These fields were rated by a proximity index. For example, a field showing 3 per cent mosaic which was 250 feet away (conditions which would disqualify for State certification) was given an index of 3/2.5 or 1.2, whereas a field with 50 per cent mosaic and 1,000 feet away was given an index of 50/10 or 5.0. Each seed plot was given as its index the highest index belonging to any of the nearest fields. The average proximity index was 3.92 for the healthy plots entered by mosaic and 0.61 for the plots that were healthy and remaining free from mosaic or that were freed from mosaic by roguing. The average proximity index was 0.83 for the healthy plots entered by leaf roll and 0.09 for the plots that were healthy and remaining free from leaf roll or that were free from leaf roll by roguing. Evidently better isolation from fields with diseased potatoes meant less chance of entrance by disease.

However, individual variation among plots was such that some with no leaf roll potatoes within several thousand feet contracted enough leaf roll to result in readings the next year of 3, 5 and even 35 per cent, whereas others with the high proximity indices of 4.0 and 9.0 had, when dug, only 0.1 per cent of their tubers diseased. With respect to mosaic, the State certification rule would have disqualified 19 per cent of the plots which produced certifiable seed stocks, and would have disqualified only 29 per cent of the plots whose progeny were non-certifiable thus furnishing poor guidance regarding the value of the plots as foundation seed.

These exceptions are not considered as evidence of weeds being sources of virus disease. Solanaceous weeds are rare in Maine and absent or practically so in the northeastern part. It is much more probable that variations in insect increase and dispersal are responsible for variations in the general effect of isolation.

Seed plots were significantly unsuccessful for mosaic control when characterized by combinations of the unfavorable factors *northeast region, medium to late development, small size,* and *poor isolation.* They were significantly unsuccessful for leaf roll control when characterized by combinations of the unfavorable factors *southwest region, medium to late development,* and *small size.*

Tuber-Unit Planting

About one-half the plots were bulk-planted and about one-half were tuber-unit planted (that is, with all seed pieces from a given tuber planted in succession along the row before the pieces from the next tuber were planted). Although tuber-unit planting permitted more complete roguing of the diseased hills and was expected to favor the success of disease control, it was learned early in the history of the project that certain other conditions often overshadowed the benefits of tuber-unit planting. For example, tuber-unit seed plots planted late in the northeastern part of the State where isolation from mosaic fields was difficult were less successful against mosaic increase than bulk-planted plots planted early in other parts of the State. Leaf roll percentages tended to be lower in stocks from bulk-planted plots than in stocks from tuber-unit plots. Therefore tuber-unit planting, although best with all other conditions equal, is not enough to overcome the unfavorable effects of certain other conditions some of which seem to be associated with it. For example, when a farmer postpones planting a tuber-unit plot until all other planting has been done, puts in a small plot to insure thorough roguing, and locates it far from his other fields but just across the fence from a diseased field of his neighbor's, he may be disappointed in the results and conclude justifiably that tuber-unit planting is not a cure-all.

Summary

Tuber-lines were helpful but not sufficient in the development of mosaic-free and leaf roll-free seed stocks in Maine. When such seed stocks were planted in seed plots, there was about a 50-50 chance that disease would enter the plot. Mosaic control was favored by location outside the northeastern part of the State, by earliness, by larger size, and by better isolation of seed plots. Leaf roll control was favored by location in the northeastern part of the State, by

earliness, and by larger size, of seed plots. The effects of these factors were often greater than the effects of tuber-unit planting.

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POTATO QUALITY VI. RELATION OF TEMPERATURE AND OTHER FACTORS TO BLACKENING OF BOILED POTATOES[1]

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INTRODUCTION

In certain of the important potato growing regions of New York State the problem of tuber blackening after boiling is serious because of its frequent and widespread occurrence and the discrimination of consumers. The discoloration appears principally in the stem-end and is present only after boiling. Several investigators (8, 18, 25) have reported that the discoloring pigment is melanin which is formed by the oxidation of certain phenolic compounds. However, Robison (17) employing solubility tests stated that the pigment could not be melanin. Nutting's (12) work also indicates that the dark pigment could not be melanin but that the precursor of this pigment is of the flavone-type substances. However, neither the mechanism by which the oxidation of the phenols to melanin or the change of flavone-type substances to the black pigment takes place in the boiled tubers, nor the environmental factors which cause the production of tubers which blacken, have been reported by these authors.

Two of the present authors have previously reported on the relation of various factors to the occurrence of blackening (9, 10, 20, 21, 22.) In the five-year period in which these investigations were in progress, more than 600 samples of potatoes grown under widely varying environmental conditions were studied. Briefly, the results obtained, some of which are as yet unpublished, show that varying levels

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or combinations of various levels of nitrogen, phosphorus, potassium, lime, and manure had no consistent or predictable effect upon the occurrence of blackening, except as they may have altered the stage of maturity with reference to weather conditions, particularly temperature. Likewise, soil reaction, soil moisture, soil type, and deficiencies of boron, copper, zinc, manganese, and magnesium had no noticeable consistent effect.

The fact that light markedly affects the balance between soluble and insoluble nitrogen in plants (11) caused the authors to investigate the effect of shading the potato vines, upon the severity of blackening and the concentration of phenolic compounds in the tubers (9). Shading increased the soluble nitrogen, total phenols, and tyrosine fractions and increased the severity of surface blackening. The amount of stem-end blackening was not appreciably increased, however.

Because of the fact that mineral nutrition, soil moisture, and light were found to exert very little influence on blackening, the study of the relation of temperature to blackening was begun. Later, a high correlation was found between the pH of a tuber or portion of a tuber and the degree and extent of blackening. Therefore, studies were initiated and are reported here on the effects of storage temperature, hydrogen ion concentration of the boiling medium, gas storage treatments, and other factors on hydrogen ion concentration of the raw tubers and blackening of the cooked tubers.

Experimental Methods and Results

With the exception of eight potato samples taken from the experimental plots of the Department of Horticulture, Florida Agricultural Experiment Station at Gainesville, Florida, all the samples used were grown by the Department of Vegetable Crops, Cornell University. After harvest the samples were placed in 40° or 50° F. storage where they remained until the various tests were made.

The boiling tests were conducted on 6 to 8 pared tubers with a standardized procedure. Precautions were taken to use the same size and kind of porcelain-lined containers, similar amounts of water, approximately the same length of time for boiling, and uniform gas flames. After boiling, the tubers were allowed to stand in air for one-half hour after which they were rated according to the amount of discoloration shown. A rating of 10 was given to samples which showed no blackening with decreasing numbers for increased blackening. Samples exhibiting intermediate blackening were given appropriate

ratings. For example, a rating of 9 was given for slight discoloration, ratings of 8 and 7 for appreciable blackening, and ratings of 6, 5, and 4 to samples which darkened severely. In this paper no ratings below 4 are reported.

The mean temperatures reported were calculated from temperature records kept on the plots where the samples were grown or from the temperature records of a nearby U. S. Department of Commerce Weather Station.

Effect of Temperature During the Growing Season on Occurrence of Blackening

In 1940 potato variety tests were located in four widely separated regions in New York, in Steuben, Tompkins, Suffolk, and Wayne counties. At the time of harvest samples of Pioneer Rural, Green Mountain, Sebago, Irish Cobbler, Chippewa and Earlaine varieties were taken from each of the four locations. In table 1 are presented for each variety the rating on blackening and the approximate mean temperature to which the vines were exposed during the last month of growth. The vines of all the varieties grown in Wayne and Suffolk counties were dead by the 20th of August; whereas, in Steuben and Tompkins counties, the early-maturing varieties (Earlaine, Chippewa, and Irish Cobbler) remained alive until about the 10th of September, and the late-maturing varieties (Pioneer Rural, Green Mountain, and Sebago) lived until they were killed by freezing temperatures in late September and early October. Thus, from the dates of maturity and the calculated mean temperature for the last month of the growing season, it may be clearly seen that there were wide differences in temperature under which the tubers of the different varieties and from different locations matured. Likewise, from the boiling test results, it may be seen that tubers from none of the varieties blackened when they matured under relatively high temperatures, and that the severity of blackening was increased as the mean temperature became lower. The late maturing varieties from Steuben and Tompkins counties matured under the lowest mean temperatures, 52° and 59° F., respectively, and blackened severely. Particularly severe was the blackening of these varieties from Steuben County.

Relation of Date of Planting to Occurrence of Blackening

It was thought that if the date of planting influenced the date of maturity, the amount of blackening might also be affected. Pioneer

Rural variety of potatoes was planted on the 6th and 20th of June, 1940, at Ithaca, N. Y. The dates of maturity were approximately the 20th of September and the 5th of October, respectively. The results presented in table 2 show that the four samples taken from those planted on the 6th of June matured under a mean temperature 6° F.

TABLE 1.—*Rating on blackening and the approximate mean temperature during the last month of growth for each of six varieties grown in four counties of New York.*

Variety	County Where Grown							
	Steuben		Tompkins		Suffolk		Wayne	
	Color*	Mean Temp.	Color	Mean Temp.	Color	Mean Temp.	Color	Mean Temp.
		Degrees F.		Degrees F.		Degrees F.		Degrees F.
Pioneer Rural	4	52	8	59	**	70	10	72
Grn. Mountain	6	52	6	59	10	70	10	72
Sebago	5	52	8	59	10	70	10	72
Cobbler	7	57	10	63	10	70	10	72
Chippewa	9	59	9	63	10	70	10	72
Earlaine	10	59	9	63	10	70	10	72

**Pioneer Rural variety not grown in Suffolk County.
*10 = white one-half hour after boiling, 1 = extreme blackening one-half hour after boiling.

higher than those planted on the 20th of June, and showed much less discoloration. The average color rating for the four samples from the earlier planting was 8.89, indicating much less blackening than is reflected in the average rating of 5.63 for the samples from the later planting.

In the similar experiment conducted in Steuben County, the planting dates were the 15th of May , the 1st and 15th of June, 1940; however, the date of maturity was not appreciably affected. The vines on all plots remained green until they were frozen the latter part of September. The calculated mean temperature of the last month of the growing season was 52° F. The average ratings on discoloration for 12 samples from each date of planting, arranged in order of planting dates, were 8.5, 8.0 and 8.0.

Relation of Date of Harvest to Occurrence of Blackening

In Steuben County samples of tubers from each of the above dates of planting were harvested on three dates,—16th of August, 7th of September, and 5th of October, 1940. At the first two dates of harvest, the tubers were immature. In table 3 are presented ratings

Table 2.—*Relation of date of planting, date of maturity, and mean temperature prior to maturity, to blackening of Pioneer Rural potatoes.*

Sample Number	Planted June 6, Mature Sept. 20		Planted June 20, Mature Oct. 5	
	Color	Mean Temperature Aug. 20 to Sept. 20	Color	Mean Temperature Sept. 5 to Oct. 5
1	9	61° F.	6	55° F.
2	8.5		5	
3	10		6.5	
4	8		5	
Average Color Rating	8.89		5.63	

on blackening and the mean temperatures for the three-week periods prior to harvest. The samples taken at the last harvest were mature by the 1st of October, and therefore, the mean temperatures for the period from the 7th of September to the 1st of October are given. At the first harvest, little or no discoloration was found in any of the samples; at the second harvest, there was considerable blackening; and, at the last harvest, the greatest amount of blackening was noted. The increase in severity of blackening parallels the decrease in temperature to which the tubers were exposed in the field.

The question may be raised whether the immaturity of the tubers from the first and second harvest might account for the presence of less blackening. In an attempt to answer this question, immature samples were harvested from potato plots at Gainesville, Florida on the 10th of April, and mature samples on the 15th of May, 1941. In this way the reverse of the temperature gradient of the

TABLE 3.—*Relation of date of harvest and mean temperature during three-week period prior to maturity to blackening of Pioneer Rural potatoes.*

SAMPLE	HARVESTED 8/16/40		HARVESTED 9/7/40		HARVESTED 10/5/40	
	COLOR	MEAN TEMP. JULY 24 TO AUG. 16	COLOR	MEAN TEMP. AUG. 16 TO SEPT. 7	COLOR	MEAN TEMP. SEPT. 7 TO OCT. 1
1	9.5	64° F.	8	55° F.	4	52° F.
2	9		7		8	
3	10		6		6.5	
4	10		7.5		5	
Average Color Rating	9.63		7.13		5.89	

previous experiment was obtained. As the tubers were becoming more mature the mean temperature was increasing. The results presented in table 4 show that in this case the immature tubers became discolored while the mature tubers did not, with the same relationship to temperature exisiting as in the previous experiment.

TABLE 4.—*Relation of date of harvest and mean temperature previous to date of harvest to blackening of Katahdin potatoes at Gainesville, Florida.*

SAMPLE	HARVESTED APRIL 10, 1941		HARVESTED MAY 15, 1941	
	COLOR	MEAN TEMPERATURE MARCH 15 TO APRIL 10	COLOR	MEAN TEMPERATURE APRIL 20 TO MAY 15
1	8	62° F.	10	76° F.
2	8		10	
3	6.5		10	
4	7		10	
Average Color Rating	7.4		10	

Summary of Cooking Tests

In the course of these investigations 232 samples including 10 varieties grown in 1940 were examined for discoloration,—the total including samples grown at six different locations in New York. The conditions of light, moisture, soil type, nutrition, and temperature under which these samples grew and matured varied widely. The color ratings were grouped and averaged according to the temperatures under which the samples matured. These results appear in table 5. In spite of such variations among the samples as caused by varietal and environmental conditions, little or no blackening was found in samples which matured at temperatures of 70° F. or higher, and blackening was by far the most severe when the tubers matured at temperatures below 60° F.

Table 5.—*Summary of the effect of temperature on blackening of samples taken during 1940 season.*

Temperature Range	Number of Samples	Average Color Rating
50° - 60° F.	113	6.56
60° - 70° F.	60	8.61
70° - 80° F.	59	9.91

Relation of Temperature in Storage to Blackening

In previous experiments it had been shown that storage temperatures of 32°, 40°, 50°, and 70° F. did not markedly affect the severity of blackening. However, when it appeared that there was a positive correlation between relatively high temperature in the field and the absence of discoloration in the tubers, it was decided to store tubers at temperatures higher than those of the previous experiments. On the 4th of February, 1941, 150 tubers grown in Steuben County, and known to blacken severely, were divided into three 50-tuber samples which were placed at temperatures of 68°, 86°, and 104° F. The 104° F. temperature was maintained in a force-draft oven and the continual removal of CO_2 (carbon dioxide) and the supplying of O_2 (oxygen) was probably responsible for the fact that the tubers did not develop blackheart until after 3 days. Undoubtedly those tubers at 104° F. lost more moisture than those at lower temperatures and with no forced draft. Seven-tuber samples for cooking tests and chemical

analyses were removed from each storage at the end of 12 hours, and at 24-hour intervals for the next four days. At the end of the 4½ day period, the remaining tubers in each of the treatments were returned to 50° F. where they remained for seven days, after which time cooking tests were again made. The seven-tuber samples were halved longitudinally and one-half of each tuber was used for cooking tests and the other one-half for analyses. The seven half-tubers saved for analyses were halved in the opposite direction and the stem end halves used for preparing samples for analysis for sugars and phenolic compounds.

The effect of relatively high temperature on the severity of blackening is shown in table 6. At 104° F. the amount of discoloration progressively decreased to such an extent that after 4½ days the cooked sample was given a rating of 9 and the amount of blackening was estimated to be about one-twentieth of that present before treatment. This experiment was repeated several times with similar results. In some cases practically no blackening was found after 1 and 2-day treatments. The boiled tubers which had been stored at 104° F. showed more yellowing; however, the stem-end blackening practically disappeared. Storage at 86° F. reduced the amount of darkening, but not as much nor so rapidly as did they at the higher temperature. The results also show that the differences in amount of discoloration in the treated samples still existed after storage for 7 days at 50° F.

TABLE 6.—*Relation of storage at relatively high temperatures for short periods to severity of blackening.*

DURATION OF STORAGE IN HOURS	COLOR RATINGS		
	STORAGE TEMP. 68° F.	STORAGE TEMP. 86° F.	STORAGE TEMP. 104° F.
12	5	5.5	6.5
36	5	6	7.5
60	4.5	6	8
84	5	6.5	8
108	5	6.5	9
Treatments stopped and samples returned to 50° F. Color rating 7 days later.	4.5	7	8.5

Because of the fact that the development of a yellow color in the cooked tissue paralleled the decrease in the amount of blackening, it was thought possible that an increase in the amount of reducing sugar might have inhibited the oxidation of phenolic compounds. The results presented in table 7 do not support this idea. The temperature treatments caused no appreciable change in the per cent of reducing sugars. However, the tubers stored at 104° F. almost doubled in total sugar, indicating an increase in the per cent of sucrose. It does not seem likely that this increase in sucrose was instrumental in preventing discoloration.

TABLE 7.—*Relation of storage temperatures to percentages of total and reducing sugars in raw tubers on basis of fresh weight.*

Hours in Storage	Storage Temp. 68° F.		Storage Temp. 86° F.		Storage Temp. 104°F.	
	Total Sugars	Reducing Sugars	Total Sugars	Reducing Sugars	Total Sugars	Reducing Sugars
12	.76	.46	.65	.32	1.07	.55
36	.71	.24	1.15	.55	.94	.32
60	.64	.34	.72	.48	.96	.37
84	.73	.51	.60	.24	1.14	.45
108	.74	.43	.73	.42	1.38	.43

According to Raper (16), the oxidation of tyrosine by tyrosinase involves the formation of 3, 4 dihydroxyphenylalanine (dopa), and that the latter compound is auto-oxidizable to melanin. It was thought that possibly dopa might be the precursor of other black pigments and its concentration in the tubers related to blackening. Dopa was estimated, using a color reaction suggested by Arnow (1), and using catechol as the standard. The results are calculated as per cent dopa on the basis of fresh weight. Tyrosine was estimated according to the method of Folin and Marenzi (5) and also is expressed as per cent of fresh weight. The results presented in table 8 show that neither the amount of tyrosine, nor of dopa, was appreciably altered by storage at relatively high temperatures, indicating that in this experiment the concentration of neither compound was directly related to blackening. It may be possible, however, that with hydroxybenzene compounds present, whether or not they result in subsequent blackening, depends on the hydrogen ion concentration of the tissue.

Relation of Storage Temperatures to Hydrogen Ion Concentration of Tubers and Blackening after Boiling

Tubers which are susceptible to blackening after boiling blacken first and more intensively at the stem end than in the remaining portion of the tuber and the hydrogen ion concentration of the stem end is lower than the remainder of the tuber. Tubers which darken after boiling in water can be prevented from turning black by boiling in an acid medium or by storage at 100° F. for 3 days; hence, the hydrogen ion concentration of the tissue of tubers was determined after storage at various temperatures.

Table 8.—*Relation of storage temperature to percentages of tyrosine and dopa in raw tubers on basis of fresh weight.*

Hours in Storage	Storage Temp. 68° F.		Storage Temp. 86° F.		Storage Temp. 104°F.	
	Tyrosine	Dopa	Tyrosine	Dopa	Tyrosine	Dopa
12	.034	.010	.034	.011	.030	.008
36	.030	.009	.028	.012	.028	.009
60	.029	.011	.029	.010	.030	.011
84	.030	.010	.028	.012	.032	.012
108	.033	.012	.029	.008	.038	.010

A glass electrode was used to determine the pH of the tissue. Lengthwise strips of tissue were removed from a number of tubers. One hundred gram samples were ground in a power liquidizer with 100 c.c. of water. Additions of water to the sample during grinding did not change the pH of the sample.

Rate of respiration was obtained of tubers stored at 34°, 52°, 68°, 80°, 90° and 100° F. by the method described by Platenius (15).

The redox potential of the tissue of tubers which had been stored at 80°, 90°, and 100° was obtained at various times during the storage period. These data were very inconsistent within treatments and are not presented here.

The respiration and pH data are presented in table 9.

The pH of the tubers stored at temperatures below 90° did not change during the course of these experiments. At 90° and 100° storage, however, the tuber tissue increased in acidity. Likewise, only those tubers which had been stored at 90° and 100° decreased in intensity and extent of blackening after boiling.

The respiration data show that the amount of oxygen absorbed increased with an increase in storage temperature up to 90° F. Between 90° and 100°, the amount of oxygen absorbed remained about the same.

TABLE 9.—*Rate of respiration and change in pH of tubers stored at various temperatures.*

Storage Temperature	Time in Storage	(Moles per 1000 Gms. Tuber per Hour)		CO_2:O_2 Ratio	pH
		CO_2 Respired	O_2 Absorbed		
° F.	Hours	10^{-5}	10^{-5}		
34	41	1.46	1.26	1.16	6.16
	81	1.19	1.10	1.08	
	134	1.04	1.01	1.03	
52	20	2.86	2.20	1.30	6.14
	41	2.56	2.14	1.19	
	81	2.82	2.54	1.11	
	134	2.48	2.40	1.03	
68	20	5.44	4.78	1.14	6.12
	41	5.16	4.92	1.05	
	81	4.4	3.92	1.12	
	133	3.8	3.56	1.07	
80	22	6.35	5.9	1.08	6.19
	40	6.74	6.5	1.04	6.14
	57	5.58	5.1	1.09	6.07
	76	5.21	4.67	1.12	6.19
90	22	8.79	6.19	1.42	6.19
	40	10.9	9.44	1.16	5.90
	58	8.5	7.04	1.21	5.95
	76	...	...	...	5.95
100	22	...	...	...	6.19
	43	12.12	7.87	1.54	5.87
	58	12.18	8.81	1.38	5.58
	76	9.86	5.34	1.84	5.60

The evolution of carbon dioxide increased with increase in temperature from 34° to 100° F. The increase in the CO_2 : O_2 ratio was significant only at the 90° and 100° temperatures. The high ratio of CO_2 : O_2 at the

high temperatures indicates that some anaerobic respiration occurs. When anaerobic respiration occurs there are a number of incomplete oxidation products formed which may include acetic, formic, oxalic, proprionic and other organic acids in addition to carbon dioxide. The decrease in pH of the tissue occurs probably as a result of the accumulation of some of these acids.

Smith (19) and others since that time have shown that tubers treated with ethylene chlorohydrin have a greatly accelerated rate of respiration. Therefore, tubers treated with ethylene chlorohydrin and subsequently stored at high temperatures will have a higher respiratory rate resulting in a deficiency of oxygen within the tubers and a larger amount of anaerobic respiration than in tubers untreated and stored at the same temperature. This possibly would result in a greater accumulation of organic acids, a lowered pH of the tuber. and a decrease in blackening. It was thought that possibly, with ethylene chlorohydrin treatment, subsequent storage temperatures could be lower than 90° to 100°, yet result in decreased blackening of the tubers.

TABLE 10.—*Effect of temperature and ethylene chlorohydrin treatment on pH and color of boiled potatoes.*

TREATMENT AND STORAGE TEMPERATURES		REACTION OF TUBER TISSUE (pH)	COLOR OF BOILED TUBERS
Untreated	50°	5.99	Slightly blackened
Ethylene Chlorohydrin	50°	6.04	Slightly blackened
Untreated	70°	5.95	Slightly blackened
Ethylene Chlorohydrin	70°	6.20	Moderately blackened
Untreated	100°	5.92	Slightly blackened
Ethylene Chlorohydrin	100°	5.25	White

Tubers of the Smooth Rural variety were treated with ethylene chlorohydrin vapor (1 cc. per liter of air space at 70° F. for 24 hours). Others were untreated but kept at the same temperature. Some lots of each were then placed at 50°, 70° and 100° F. for two days. The pH of the tissue was determined and the color of the boiled tubers observed at the end of the two-day period. The results are shown in table 10.

At 50° and at 70° the pH of the tubers which had been treated

with ethylene chlorohydrin was slightly higher than that of untreated tubers, although the difference at 50° is not significant. Apparently the increase in respiration of ethylene chlorohydrin treated tubers at 50° and 70° is largely aerobic, probably resulting in an increased concentration of carbon dioxide within the tubers. This increase in carbon dioxide may be sufficient to increase slightly the pH of the tuber tissue. The difference in pH between the treated and untreated tubers at 50° apparently was not sufficient to result in any differences in blackening of the tubers. At 70°, however, the pH change was greater and the treated tubers blackened to a greater extent than the untreated. The increased rate of respiration of the treated tubers at 100° undoubtedly was accompanied by an increase in anaerobic respiration and the formation of organic acids. This accumulation of organic acids probably resulted in the low pH of the tuber tissue which was accompanied by an absence of blackening in the boiled tubers. Blackheart, however, was present in all tubers which had been treated with ethylene chlorohydrin and subsequently stored at 100° F.

Tubers of the Smooth Rural variety grown in 1940 and which had been stored until the 12th of August, 1941 at 50° F. were then placed in constant temperature compartments at 80°, 90° and 100° F. After 72 hours, one lot of tubers was removed from each compartment, pared and boiled. Tubers which had been stored at 80° F. blackened as much as those at 50° F. Tubers stored at 90° and 100° for 72 hours did not blacken when boiled. After 144 hours at 80° tubers still blackened after boiling, whereas those at 90° and 100° did not blacken. These latter tubers showed a tendency to remain hard longer during the boiling process than those stored at the lower temperatures.

In order to determine more accurately the minimum length of time necessary for potatoes to be stored at 90° to prevent subsequent blackening in old tubers, a large lot of the 1940 crop of Smooth Rural tubers was placed at 90° F. in September, 1941. These tubers had been stored at 50° F. ever since being harvested,—11 months earlier. It took approximately 6 hours for the interior of the tubers to reach the temperature of of the air in the compartment. At 8-hour intervals, lots of tubers were removed from the 90° temperature and boiled for determination

of degree and extent of blackening. The following results were obtained:

Length of Storage at 90° F. (Hours)	Color of Tubers One-Half Hour after Boiling
0	Very black
8	Very black
16	Very black
24	Very black
32	Very black
40	Very black
48	Very black
56	Moderately black
64	Moderately black
72	Slightly black

A storage period longer than 72 hours for old tubers at 90° did not result in complete disappearance of the blackening as it did when the tubers were physiologically younger.

To determine whether the change in pH and degree of blackening after boiling induced by high storage temperature was temporary or permanent, lots of Smooth Rural tubers of the 1940 crop were placed at 100° for 3 days in August, 1941 and then removed to 50° storage for 6 weeks.The tubers blackened considerably and had a reaction of pH 6.16 before placing at 100° F. At the end of 3 days at 100° the reaction was pH 5.60 and the tuber did not blacken after boiling. After 6 weeks at 50° those previously stored at 100° F. had a reaction of pH 6.05 and blackened slightly but not to so great an extent as those stored constantly at 50° and with a reaction of pH 6.17.

Gas Storage Treatments

Since anaerobic respiration in the tubers would result in accumulation of certain organic acids and consequently in a decreased pH of the tissue, tubers of the Mesaba variety, which were known to blacken after boiling, were placed in an atmosphere and at a temperature which would be conducive to anaerobic respiration. Other gases and combinations of gases were employed that resulted in an increased pH of the tubers. The tubers were then boiled and observed for degree and extent of blackening. The length of storage under these conditions was 48 hours. The results of these studies are presented in table 11.

When the tubers were stored in nitrogen gas, the carbon dioxide produced was absorbed by NaOH (Sodium hydroxide) in the bottom of the container. There was a definite decrease in pH of these tubers within 48 hours. When stored very much longer than this the tubers decomposed. A high temperature was employed to hasten the effects of the gases since the high temperatures increase the rate of respiration whether aerobic or anaerobic. The decrease in pH was accompanied by an absence of blackening.

TABLE II.—*Effect of storage temperatures and gases on pH and blackening of tubers after boiling.*

STORAGE GAS	TEMPERATURE DEGREES F.	pH OF TISSUE AFTER 2 DAYS STORAGE	DEGREE OF BLACKENING OF BOILED TUBERS
Air	50	6.25	Slight
Air	100	6.22	Slight
100% N_2 CO_2 absorbed	100	5.47	None
60% CO_2 40% O_2	100	6.38	Very black
60% CO_2 40% N_2	100	5.75	Grayish cast*

*Appears to be a different type of darkening.

Tubers stored in air at 100° F. for 2 days did not decrease in pH or in degree of blackening. Many of our other experiments show that at 100° F. the increase in acidity and the decrease in blackening usually occur between the second and fourth days of storage.

Carbon dioxide was mixed with several other gases as a storage medium (23). Thornton (23) found that when potatoes are stored in carbon dioxide with oxygen present, the tubers increased in pH. The above data corroborate his findings and also show that when the same percentage of carbon dioxide is mixed with nitrogen instead of with oxygen and tubers stored in it, that the pH of the tissue decreases.

When no oxygen or an insufficient amount is present anaerobic respiration occurs resulting in the formation of several organic acids. These acids may accumulate in sufficient quantity to offset the effects

of the accumulation of CO_2 so that the resultant tissue is more acid rather than less acid. This probably is what has occurred at 100° F. with a combination of 60 per cent carbon dioxide and 40 per cent nitrogen gases. When stored in 100 per cent nitrogen with the carbon dioxide of respiration absorbed by NaOH the tubers became still lower in pH probably because carbon dioxide is not present to counteract some of the acidifying effects of the organic acids.

Effect of Hydrogen Ion Concentration of Boiling Medium on Blackening of Tubers

Since it was found that storing tubers at high temperatures and in certain gas concentration decreased the blackening after boiling and that the hydrogen ion concentrations of these tubers was increased, it was conceived that possibly the severity and extent of blackening could be altered by the use of various substances in the boiling medium. Tinkler (24) found that potatoes steamed over water containing a little ammonium carbonate were dark in color after cooking and if potatoes which normally blacken are cooked in water containing a little acetic acid, they were usually better than if cooked in tap water. Nutting and Pfund (13) also found that citric acid, lemon juice or vinegar in the cooking water reduced stem blackening.

(*Hydrochloric acid*) *HCl.* Tubers which blackened when boiled in water did not blacken when boiled in a solution of 0.1 N HCl. The starch of the tubers, however, appeared to have gelatinized considerably resulting in decreased mealiness. Solutons of 0.001 N HCl prevented blackening and did not gelatinize the starch as much as the 0.1 N solution. HCl solutions of 0,0001 N and less did not have much effect either on the blackening or texture of the tubers. This was probably because of the buffer action of the potato preventing an appreciable change in the pH of the tissue. The pH of the raw tuber before boiling in 0.0001 N HCl was 6.20 and after boiling it had the same hydrogen ion concentration.

Since it was desirable to test the relation of $H+$ concentration of the cooking medium and of the cooked tuber to blackening, it seemed important to use chemicals with the same cations and anions with the exception of $H+$ and OH^- ions in order to eliminate the possible effects caused by different ions. NaH_2PO_4 (Sodium dihydrogen phosphate) of pH 4.5 and Na_2HPO_4 (Disodium hydrogen phosphate) of pH 9.6 seemed desirable reagents for this purpose.

(*Sodium dihydrogen phosphate*) NaH_2PO_4. After boiling pota-

toes in buffer solution of .05M NaH_2PO_4 of pH 4.5 the tubers did not blacken. The color and texture of these tubers were similar to tubers which had been placed at 100° F. for 3 days.

(*Disodium hydrogen phosphate*) Na_2HPO_4. A buffered solution of Na_2HPO_4 of pH 9.6 caused an increase in the intensity of blackening but did not greatly gelatinize the starch of the tuber. Tubers of the Mesaba variety blackened very extensively when boiled in a solution of Na_2HPO_4 of pH 9.6. The tubers had a reaction of pH 6.61 after boiling. When boiled in a solution of KH_2PO_4 (Potassium dihydrogen phosphate) of pH 4.5 no blackening of the tubers resulted. The reaction of the tubers in this case was pH 5.85.

Sodium hydroxide (*NaOH*). Low concentrations of NaOH had no apparent effect on either darkening or texture of the tubers probably because of the buffer action of the tuber tissue preventing a significent change in the hydrogen ion concentration of the tissue. A 0.0001 N NaOH solution of pH 10.0 caused no change in degree of blackening. A 0.1N NaOH solution considerably gelatinized the starch and greatly increased the degree of blackening. These tubers, however, turned quite yellow at first and did not blacken until after several hours. The blackening appeared to be more of the blue-black shade than that appearing naturally.

In order to determine if OH ions would cause blackening to occur in tubers which did not normally blacken, tubers which when boiled in water showed no blackening, were boiled in NaOH solutions of various concentrations. These data are shown in table 12.

TABLE 12.—*Effect of concentration of NaOH in the boiling solution on blackening of tubers.*

NaOH CONCENTRATION	COLOR OF TUBERS AFTER BOILING
0	White
0.006 N	White
0.013 N	Very slightly blackened
0.026 N	Some yellowing followed by slight blackening
0.032 N	Medium blackened
0.064 N	Black Turned yellow, then black
0.096 N	Very black

Several hours elapsed before the tubers which had been boiled in the 0.013 N solution became blackened.

When the boiling medium was made more alkaline by several other reagents the results were as shown in table 13.

TABLE 13.—*Effect of OH ion concentration in the boiling solution on blackening of tubers.*

BOILING MEDIUM	COLOR OF TUBERS AFTER BOILING
Water	White
Na_2CO_3	Very blue-black
Na_2HPO_4	Slightly blackened
$NaHCO_3$	Very blue-black
NH_4OH	Slightly blackened
NH_4OH*	Moderately black

*Further added as it boiled out.

Tubers boiled in the solutions of Na_2CO_3 (Sodium carbonate) and $NaHCO_3$ (Sodium bicarbonate) did not blacken until several hours after boiling.

EFFECT OF BOILING TUBERS IN BASIC, ACIDIC, REDUCING, AND OXIDIZING SUBSTANCES ON SUBSEQUENT BLAGKENING

Since it has been shown that boiled tubers turn black after exposure to air and are prevented from blackening by confining in an oxygen-free atmosphere (24) it seemed likely that the oxygen in the air was necessary to develop the blackening. Tinkler thus showed that this blackening is an oxidation process. Hence, potatoes that blacken when exposed to the air after boiling probably would turn black while being boiled in an oxidizing solution. Conversely, tubers boiled in a reducing solution possibly would be prevented from blackening or retarded in this process even after exposure to air

$KBrO_3$ (Potassium bromate) was employed as an oxidizing agent and SnC_2O_4 (Stannous oxalate) as a reducing agent. Potatoes were boiled in these solutions alone as well as when combined with Na_2HPO_4 or NaH_2PO_4. SnC_2O_4 brought to the same pH as the tuber was used because it supplies a small but constant amount of reducing material because of its relatively low solubility in water. Neither the SnC_2O_4 nor the $KBrO_3$ solutions had any appreciable effect on the tex-

ture of the tubers. The results of the effects on blackening are shown in table 14.

TABLE 14.—*Effects of boiling tubers in reducing and oxidizing agents at various hydrogen ion concentrations on subsequent blackening of the tubers.*

BOILING SOLUTION	BLACKENING OF TUBERS AFTER BOILING
SnC_2O_4 (brought to same pH as tuber)	None
$SnC_2O_4 + Na_2HPO_4$	Very slight
NaH_2PO_4	Slight
Water	Moderate
Na_2HPO_4	More than with water
$KBrO_3 + NaH_2PO_4$	Moderate intensity, but extensive
$KBrO_3$	Very extensive, brown-black
$KBrO_3 + Na_2HPO_4$	Very black with brownish tinge

When tubers which had been boiled in water were further boiled in 0.05N HCl the black color disappeared and starch was gelatinized to some extent. Tubers which had been boiled in a solution of NaH_2PO_4 turned blacker when boiled in 0.05N NaOH and exposed to air for several hours. Tubers which blackened when boiled in tap water became white after being boiled in a solution of SnC_2O_4. However, tubers which had been boiled in SnC_2O_4 solution did not turn black when subsequently boiled in $KBrO_3$ solution. The blackening caused by boiling in $KBrO_3$ solution appeared in the stem ends of the tubers first and later over the entire tuber when a strong solution was used. There was a brownish tinge to this type of blackening.

More work should be done on the relationship between reducing and oxidizing agents before their effects on blackening can be stated. It may be possible that all reducing agents prevent tubers from blackening and that oxidizing agents increase the blackening. A strong reducing agent which does not precipitate in basic solution should be used to make comparisons between solutions of various hydrogen ion concentrations as to its effects on blackening.

OXIDATION-REDUCTION POTENTIALS OF TUBER TISSUE

One hundred grams of tubers were ground in a liquidizer with 100 c.c. of water. A platinum electrode in the tuber tissue served as

one-half cell and connected with a calomel half cell by an agar-KCl salt bridge.

The oxidation-reduction potential was very inconsistent and time variable. There was no consistent relationship between the oxidation-reduction potential and blackening of the tubers after boiling.

Reducing Properties of Tubers

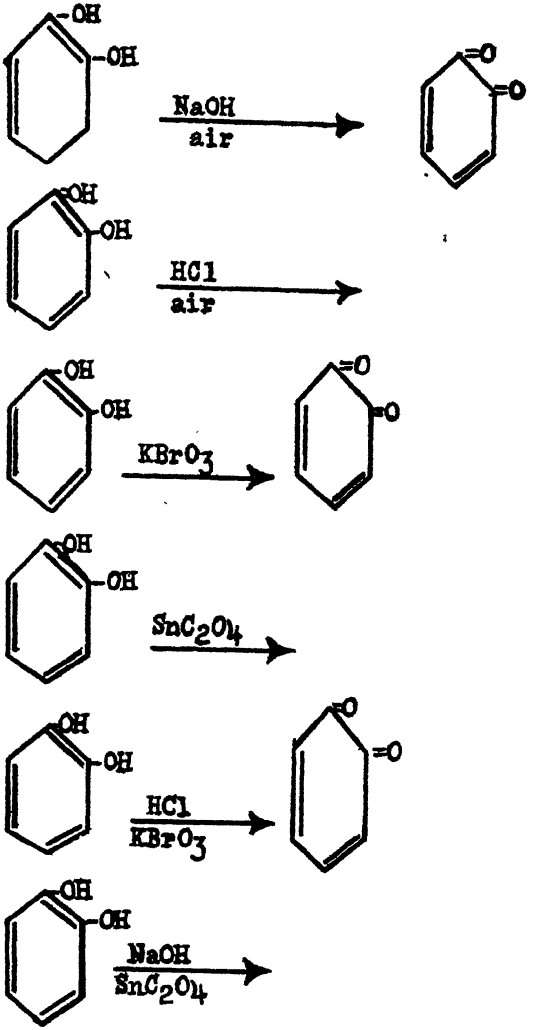
Lengthwise segments of tissue were removed from a number of tubers and 100-gram samples ground for 2 minutes at high speed in an electric liquidizer with 50 c.c. of a mixture of 2 per cent H_3PO_4 (Phosphoric acid) and 2 per cent H_2SO_4 (Sulphuric acid). The acid inactivated the enzymes in the tissue and prevented formation of pigments by enzymatic action. Ascorbic acid is stabilized by this acid mixture.

Using 50 c.c. portions at a time, 300 c.c. of the mixture was used to quantitatively transfer the tuber tissue to a 500 c.c. graduate. After standing for one hour the mixture was filtered and aliquots used for analyses. The liquidizer beat air bubbles into the mixture which adhered to small potato particles causing them to rise to the surface. With the use of a large pipette the clear solution was removed and filtered by suction. Twenty-five c.c. of this solution was diluted with 50 c.c of water, 25 c.c. of 0.01 KIO_3 (Potassium iodate) and 5 c.c. concentrated HCl added immediately and the solution allowed to stand for 15 minutes. Five c.c. of 5 per cent KI (Potassium iodide) was added and the solution titrated with 0.01 N $Na_2S_2O_3$. (Sodium thiosulphate). The time of the KIO_3 oxidation is very important. There was no difference between tubers stored at 50° and those stored at 100° F. for 3 days in reducing power toward KIO_3.

Possible Compounds Responsible for Blackening

From the results of the experiments mentioned previously in this paper, one may conclude that potatoes which would blacken after boiling in water can be prevented from blackening by boiling in solutions such as hydrochloric acid and stannous oxalate. Increased blackening can be obtained by boiling tubers in solutions such as sodium hydroxide or potassium bromate. Blackening also results when the tubers are boiled in a solution of hydrochloric acid and potassium bromate but no blackening occurs when they are boiled in a solution of sodium hydroxide and stannous oxalate. There are certain organic compounds which are quite common in potatoes which may react with the

above chemicals resulting in the color changes noted. These compounds are hydroxybenzenes.



Taking orthodihydroxybenzene as an example of this group, the following indicates their possible reactions:

(orthobenzoquinone)

Not so much tendency to form quinoid structure.

No tendency to form quinone.

No tendency to form quinone.

The quinone compounds are usually colored substances. The data obtained substantiate the possibility of the formation of such quinoid structures, especially since the reactants are present in potatoes.

Discussion

From the results it is apparent that temperature is related to the occurrence of blackening. Tubers maturing under low temperatures (50°-60° F.) were found likely to blacken whereas those maturing at higher temperatures (70°-80° F.) seldom showed any discoloration. High temperatures in storage for 3 to 4 days prevented blackening. The question which arises, therefore, is what changes take place in the tubers, because of high temperature, which decrease or prevent blackening? It would be logical to assume that the effects of temperature on the blackening mechanism would be similar for tubers maturing in the field and in storage. The effect of temperature in storage was found not to be related to the amounts of tyrosine or dopa, and other results (unpublished) indicate that high concentrations of dopa are not necessarily associated with severe blackening. The pH of the tuber, however, may influence this reaction. It was thought possible that high temperatures might reduce dopa to tyrosine but the data obtained do not substantiate this.

In the light of the results of the present paper, together with those obtained by others, the authors offer suggestions concerning the effect of temperature on one possible mechanism involved in the production of the black pigment. Figge (4) reports that the production of melanin from tyrosine by tyrosinase is regulated partially by the oxidation-reduction potential. It is possible that the formation of other black pigments from hydroxy compounds also is regulated by the oxidation-reduction potential. Fredrich (6) found that tubers stored at warmer temperatures showed lower oxidation-reduction potentials than those stored at cooler temperatures. It seemed possible, therefore, with a lower oxidation potential caused by the high temperatures, that either the precursors of the black pigment would not be formed or, if formed, would not be further oxidized. In the present studies, however, no consistent relationship was found between the oxidation-reduction potential and blackening of the tubers after boiling. It is suggested that in future studies the effect of temperature on the presence of the oxidized and reduced forms of glutathione, ascorbic acid, cytochrome, iron, and copper be studied. At high temperatures and with O_2 limiting, these substances would tend to occur in the reduced state and thus not aid in oxidative reactions.

The possible rôle of the phenolic compounds in respiration and formation of black coloration might also be considered. According to the theories on the mechanism of respiration of Palladin (14) and Blackman (2), phenolic compounds act as the principal hydrogen acceptors in the respiratory process and molecular O_2 is used primarily in oxidative regeneration of these hydrogen acceptors. In more recent studies, Boswell and Whiting (3) report that a system, involving phenolic compounds as the hydrogen acceptors, accounts for two-thirds of the total respiration in potato tissue. Since at high temperatures respiration would proceed at a faster rate, the amount of O_2 in the tissues would become proportionately less at high temperature. Magness (7) found almost twice as much O_2 in potato tissue at 11° C. as at 22° C. Thus, at high temperatures and with O_2 limiting, phenolic compounds would tend to remain in a reduced state. With the phenolic compounds in such a reduced condition and with oxygen limiting it seems probable that they would tend not to be oxidized to the black substance in the boiled potatoes, assuming that phenolic compounds are precursors of the black color.

Both of the above hypotheses depend upon high temperatures to place in a reduced condition the various compounds which form the total oxidation-reduction system, as well as to reduce the phenolic compounds which may be the precursors of the black pigment.

The present studies show that the black color does not appear or, if present, will disappear when the tuber tissue has a high hydrogen ion concentration. Conversely, the black color appears or increases in intensity in tissue of lower hydrogen ion concentration. Almost without exception, the stem ends of tubers which blacken have a lower hydrogen ion concentration than the opposite ends of the same tubers. Also, this type of blackening always occurs first and in greater intensity at the stem end than in the apical end of the tubers. These color reactions appear regardless of whether the pH differences occur as a result of growing conditions, storage temperatures, certain gas storage, or boiling media. It is pointed out that possibly the hydroxybenzene compounds of potato tubers are the precursors of the black coloration.

It is not assumed from the evidence obtained in these experiments that among the many environmental factors affecting growth and composition of plants, temperature is the sole factor influencing the occurrence of blackening. It is believed that interactions between light and nutrition may also be important. The results are complicated by the fact that as temperatures were decreasing, days were becoming shorter, light becoming less intense, quality of the light changing, and

the per cent of sunshine decreasing. However, as shown in previous work, altering light intensity, widely varying the types of nutrition, varying soil moisture and reaction, had little effect on blackening and it is now believed that any effect they might have would be expressed principally at relatively low temperatures.

The results warrant some suggestions to growers in regions where the problem of blackening is serious. Those who have had to contend with the problem have been puzzled about the cause of blackening and have been seeking means of preventing it. The use of varieties that mature earlier than Pioneer Rural, Green Mountain, and Sebago, wherever feasible, is suggested. Earlier planting dates are suggested where the date of maturity can be influenced by the date of planting. Any means of maturing the potatoes before low temperatures prevail in the fall should tend to reduce blackening. Storing potatoes at 90°-100° F. for 3 or 4 days within several weeks preceding their consumption will greatly reduce or prevent blackening and will prevent its recurrence for several weeks, even though they are subsequently stored at low temperatures.

Summary

The results of the authors' previous work on the problem of blackening of boiled potatoes are reviewed briefly. Nutrition, soil moisture, soil reaction and light had been found to exert little effect on the occurrence of stem-end blackening with the exception of their effect on time of maturity.

In the 1940 experiments, 232 samples of potatoes grown in six different regions of New York State were examined for discoloration after boiling. In spite of variations among the samples caused by variety and environmental conditions, little or no blackening was found in samples which matured under mean temperatures of 70° F. or higher, and samples which matured under mean temperatures of 60° F. or less usually blackened. The regions in which the problem of blackening was most severe had the lowest mean temperatures during the time when the tubers were maturing.

In regions where the problem of blackening is serious the use of earlier maturing varieties than the Pioneer Rural, Green Mountain, and Sebago, wherever feasible, is suggested. Earlier planting dates are suggested where the date of maturity can be influenced by the date of planting. The results indicate that any means of maturing the potatoes before low temperatures prevail in the fall will tend to reduce the amount of blackening.

Exposure of tubers, known to blacken severely, to temperatures of 100° F. for 3 to 4 days prevented practically all blackening in the tubers when they were boiled. Storage temperatures of 90° for several days also reduced the amount of blackening. Analyses for total sugars, reducing sugars, tyrosine, and dihydroxyphenylalanine were made, but the results did not help to explain why high temperatures in storage reduced the amount of blackening.

A discussion of the possible effect of temperature on the blackening mechanism is presented.

A high correlation exists between the hydrogen ion concentration of tuber tissue and the degree of blackening. The pH of tubers which blacken is higher at the stem end than at the apical end and the blackening occurs first and to a greater degree at the stem end than at the apical end. The hydrogen ion concentration of tubers can be increased and blackening decreased by storage at high temperatures, storage in certain gases or boiling in certain acidified solutions. The hydrogen ion concentration can be decreased and blackening increased by storage in certain gases or boiling in certain alkaline solutions.

There was no consistent relationship between the oxidation-reduction potential of the tissues and subsequent blackening of the cooked tubers. No differences in reducing power toward KIO_3 were found among tubers stored at 50° and those stored at 100° F.

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THE AID OF EXPLORATION IN POTATO IMPROVEMENT

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INTRODUCTION

The searches for wild potatoes, especially the species *Solanum tuberosum* L., conducted in South America from time to time have followed no consistent program. An unknown number of collections by various agencies have been made over the past one hundred years. The recent Russian expedition was the most far-reaching in the expanse of territory examined and the number of botanical decisions rendered. If searches, as a whole, have tended to be haphazard in their relations to each other, it is partially due to the history and the nature of the potato itself, and to the cost of carrying to a satisfying conclusion the persistent search demanded. The study, definition and evaluation of additional tuber-bearing solanums would be a contribution to botanical science. A vigorous program designed for further search for indigenous clones and seedlings of *Solanum tuberosum,* especially any which may be regarded as the parental strain should be supported as a contribution to science, an economy measure, and an aid to practical agriculture.

Being conservative in crop plant improvement today means fol-

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lowing an ambitious breeding program. This requires the support of the contributing plant sciences, and must be furthered by a wide exchange of seeds and plants, and the search for and introduction of fundamental indigenous stocks where that is possible. It is a major factor in any national agricultural economy. For a number of years there have been special efforts made to improve the potato in the United States. Next to the cereals the potato is the world's most valued food plant, and is in need of improvement in several important directions.

The circumstances surrounding the introduction of the potato into Europe and hence into North America, have left doubt and created uncertainty and confusion concerning the specific origin and derivation of the plant we now value so highly. Although the question may not be conclusively answered regarding the heredity of the potato, it does have an influence on future work. The question of origin is constantly before us. Is the cultivated potato in its improved form a true descendant without marked deviation from the original parents? What is this origin? Is anything to be gained by a further search for additional potatoes, and especially for the parental line of *Solanum tuberosum?* Where should such a search properly be conducted?

Circumstances Affecting Potato Introduction into Europe

Much has been said about the introduction of the potato into Europe. There is as yet no documentary evidence about the acceptance of the potato there until it was reasonably well established. A brief consideration of the times and circumstances of the early days may help to formulate some practical opinions about it, because the indifferent introduction has tended to set the accepted pattern ever since. It is an unromantic story, more confused than mysterious.

The successors of Columbus soon learned their way about the world. During the Age of Discovery (circa 1500-1750) there were able navigators in all the maritime nations. They were commonly men distinguished in seamanship, anxiously developing the practical knowledge of the art of navigation; valiant adventurers, ambitious explorers, and usually able fighters. They were urged, of course, by the anticipated rewards of daring, of conquest, and of fortunate circumstances. Their ships were of small burden, poorly designed and constructed, the gear subject to rapid deterioration. In the earlier years their accounts are filled with brief, but significant descriptions of the utterly wretched conditions of their existence at sea: starved, thirsty, cold, sick, incapacitated by malnutrition, lice, wounds, or dying from scurvy. The food spoiled under the tropical sun, became worm-infested or rotted. In

addition to this there was the decaying meat, stinking water, wormy bread and meal; and the vile conditions which prevailed arising from dirty men in dirtier ships. They were always fearful of the storms and of the staunchness of their ships, the teredo, the fates of an unknown coast, and innumerable other hazards.

Magellan discovered the Straits in 1520; Pizarro reached Peru in 1532; Chile was ostensibly taken in 1550; and Chiloé and the archipelago were claimed for Spain by 1567. From the discovery of the Straits until the end of that century less than fifteen expeditions passed successfully through them, and during the next century there were still fewer. In the eighteenth century there were several successful passages, however, as ships and seamanship improved. Navigation along the Pacific coast south of Panama increased, for it was the only satisfactory means of communication in this enormous colonial acquisition. The fertile lands of Chile became the commissary for Peru, the land of gold. The ships of other nations, having few territorial claims, came to prey on the Spanish. But to all of them food, water and fuel remained as problems on a long voyage, not merely to postpone starvation, but to maintain health. While there was no full comprehension of the relation of diet to scurvy until later, the importance of certain green and succulent herbs was appreciated, as the early designation of *Cochlearia officinalis* as "scurvy grass" testifies. For use on ships the discovery of potatoes was a major event. It was a vegetable of good keeping quality, easily cooked, appreciated as a food, and an adjunct to health. Chuño, the desiccated tuber prepared by the Andean native, became an article of commerce among the Spaniards, valued where men worked at the mines, and may have been used on shipboard as well.

To the natives of Peru and Chile the potato was a most important food, and the Spaniards saw and understood its value. The potatoes of Colombia, Ecuador and Peru, the first they encountered, were not of the best keeping quality, nor of satisfactory size. The coastal traffic carried potatoes from the south to the north, and in time across Panama and beyond. As the historian Herrera and other writers of the early days indicate, the people preferred potatoes from the South and of Chiloé because they were larger than they were anywhere else. Navigators learned and remembered these things. In 1592 Capt. John Davis was caught the second time in the utterly foul weather at the Straits of Magellan, the ships were battered, the crew was dying of hunger and scurvy, and the desperate and diminishing company were counseling what best to do. He promised them, if they would sail with him north in the Pacific, that at the Isle of Santa Maria would be found "wheate,

porke, and roots enough." (5) Potatoes were brought to Europe under unusual circumstances, not once but many times, and entered the various ports in many ships. They came as an item of the food stores, not of the cargoes. People of other nations acquired them, for in capturing a Spanish galleon the food it carried was not overlooked.

The men before the mast were often farmers or the sons of farmers, and were interested in growing such a novel crop. For one thing, the tubers were of striking appearance because of the colors displayed. By these indifferent ways the potato became established among the initiated after many trials, no one of which could be pointed out as an introduction, certainly not as a formal introduction. By 1600 the potato of Chile had already demonstrated its superiority in size and stability. The opinions and enthusiasms of Baukin, Gerarde and Clusius, as well as other intelligent men, appeared in herbals and other written accounts and initiated the historical record. The potato arrived unannounced, unheralded and unrecorded, cherished by those whom it had nourished and restored abroad, and proving itself by pure merit in the new home.

The potatoes which came to the ships were of a cultivated sort, though among them were some not as yet far removed from the wild varieties. The natives used competent and efficient agricultural methods. All their crops were planted, cultivated and harvested, and among these the potato held a high rank. There was no need for mariners to search the wilds, nor were they interested in such a search. Condition, size ,and sufficiency were apparently their chief concern, and what they required could best be found in the fields and storage of the natives. The potato which went to Europe and persisted had already been subjected to cultivation and some to selection. All these facts have not been proven, but are inferences designed from circumstances known to us, and the habits of men throughout the ages.

Subsequent Development

During the years that followed, the slow improvement of the potato in Europe was from tuber selections, or from seed produced on the plants growing there. New additions from South America appeared from time to time, but apparently they accounted for no outstanding improvement. By 1750 the potato was widely grown, relatively speaking, and during the next fifty years a large number of varieties came to be distinguished, and the value and need of general improvement further appreciated. By 1815 the Vilmorin collection was begun at Verrieres-le-Buisson. This was to be maintained for nearly one hun-

dred years. Later in England, there was great activity, especially in breeding; but this activity was not prevalent to an equal extent in America.

There have been additional introductions of the potato from South America from time to time, both of tubers and of seed. The methods followed in collecting them have generally been of the same pattern. The potato tubers were collected in the markets, from the natives, or from stocks on hand. The seed was collected from fields where potatoes were being grown, but not often in the forest where they could be considered indigenous, and too commonly with insufficient information about the plants from which they came. The interest of the taxonomist collecting specimens resides in the flower and sometimes in the fruit, but seldom in the tuber. The time and labor required for proper search and collection have operated to defeat a methodical, continued, adequate study in the field of the truly indigenous, free-growing potato, in an environment unassailed by the influences of any human culture. A part of the old territory should be searched again, and also some adjacent sections which have been beyond the reach of hurried collectors. These remaining places, it is to be hoped, are beyond the lands which were easily accessible to the free-ranging Araucanian in the days of his supremacy.

The new knowledge about potato characteristics and habits, the floral and leaf features of the many species, their chromosome numbers, geographical ranges, uses, and cultural spread have changed the value of the earlier expressed opinions. Humboldt, Ruiz and Pavon, Meyer, Sillman, Andre, Baker, Berthault, Sutton and Labergerie, to mention only a few, contributed greatly to our knowledge of the potato, its taxonomy and improvement. Had their work and observations been aided and augmented by our skills in cytology, genetics, and plant breeding, our knowledge of the potato, its history, improvement, disease control, and uses would be greatly extended.

Where the Potato Has Been Found

There are numerous potato species found from Mexico to Chile, but it is only *Solanum tuberosum,* the potato of commerce, which is of concern here. The prevailing and considered opinion assigns the Chilean region south of the Rio Bio-Bio, as far as the Seno de Reloncaví and somewhat beyond, an extent of approximately 400 miles, and the adjacent islands, as the probable home of the potato. The former is one of the famed agricultural regions of the earth. The soils are extremely fertile and well watered, and are drained by a thousand

streams. Formerly there was a dense native vegetation, the dark forests of Araucania, extending through the plain up into the slopes of the Andes. In the meadows, mountain parks, islands of the rivers, and the areas burned to afford additional grazing for the huanacos of the Araucanians, the potato could be found, or was grown. The Araucanians were not essentially tillers of the soil, though they used all of its products and partially depended on crops for their sustenance. The forest yielded many foods, of which the potato was the most highly prized. But the better sorts of potatoes were found progressively southward, with increasing numbers of varieties and strains.

One writer claims that the potato was discovered in its wild form in the mountains of Nahuelbuta. Cãnas (1) contends that it grows naturally near Cayucupil on the banks of the Rio Cautin near Temuco, and extends into the riparian lands of the Rio Imperial; in the coastal mountains of the Province of Valdivia from Tolten to Corral. It is found in the fertile fields of the Andean foothills, the slopes of the divides, and the passes of the lake region, from Villarrica south to the Lago Llanquehue and the hills of Tronador. Potatoes have also been found in the neighboring islands to the south, especially on Chiloé, sometimes claimed as the center and possible point of origin. Potatoes have been obtained from these parts many times during the years. They have been collected from those who grew them, or more rarely found by some plant explorer. The nature of the plant does not lend itself to rapid or easy collection. Its life span has to be followed for suitable results. Again, mankind has lived there for too long a period. One is unable to assure himself that the potato has not been manipulated before and spread around by artificial means. Small localities frequently have a preferred sort or variety, which satisfies some whim or flavor or culture, and which qualities are not desired so highly elsewhere.

The Guiding Elements

Where should one search for these enigmatical potatoes? To orient us in this respect are certain characteristics and preferences demonstrated by the potatoes we have at the present time. The root system is small in relation to the vine and to the weight of tubers which is produced. The vine is subject to wilting and serious injury if the wilting is continued too long. The potato, then, has adjusted itself to very frequent rainfall, economizing on root development because of the availability of water. Yet both the tuber and the root suffer promptly from an excess of water about them. It is far from

an aquatic plant. It grows best in soil frequently wetted and constantly drained. Fertility is also a factor of importance. The cultivated potato suffers from unbalanced soil nutrients, and this unbalance is soon manifested in the health of the vine, and results in the decline of floral parts or tubers. Ranges of temperature may be endured, but with the exception of certain other tuber-producing Solanum species, the vine will endure no frost nor freezing of the tuber; although cool temperatures are required for the best development. When winter comes the ground must be protected by an ample layer of snow so that the tubers may remain frost-free and be preserved until the following spring. The soil should have an acid reaction, preferably about pH 5.5. An acid reaction is to be expected in a volcanic region.

The range within which the potato has best developed in the northern hemisphere leads one to expect it in the southern hemisphere in comparable latitudes, but this is not wholly the case. One finds excellent potato-growing conditions in Ireland and adjacent latitudes in Europe, but not in the barren lands of the Territorio de Magallanes, equally far from the equator. In the United States the fortieth parallel is accepted as the southern boundary of the region of main crop production.

The Plants to Be Sought

The search should be made for three groups of plants. The first group should embrace the tuber-bearing *Solanum tuberosum* sorts similar to the potatoes we have now, and which may carry new or better qualities in any one of the several desired categories of improvement. These will resemble the types already collected, but among them may be some carrying factors dominant in the desired lines, as well as tendencies not yet detected in the potatoes at hand. These would, at the present time, be useful in a breeding program.

The second group would comprise the so-called "parental strain" which, it may be assumed, is the direct vegetative descendant of the earliest *Solanum tuberosum*. From this line the others will have branched off as seedlings, being crossed and recrossed, to give the numerically great variation in tuber appearance which is found today in these natural growing regions. These parental strains should predominate in their native localities, and to them the characteristics found in other strains would have had their origin. That such strains may be found, or could be recognized as such, if found, is problematical at this time. Suffice it to say that an adequate search for them has yet to be made.

The third group of solanums contains those which by polyploidy may have produced the now recognized *Solanum tuberosum*. In view of the opinions of Müntzing (6), Jorgensen (3), Rybin (7), Juzepczuk and Bukasov (4), Winge (10) and others, the 48-chromosome potato may well have developed by polyploidy as a hybrid of two 24-chromosome parents. This may have happened many times, giving rise to different types or strains in the 48-chromosome Chilean group. It may involve more than two different parent species. This hybridization of diploid species, resulting in polyploid offspring which are stabilized and reproduce as the 48-chromosome species, may indeed be in the process of accomplishment today. These 24-chromosome plants may not be themselves tuber-producing plants, and may not greatly resemble the types with which we are familiar. According to Winge's contention the plants formed by this hybridization will be of constant, new, and probably intermediary form between the parents. Jorgensen is of the opinion that among solanums and other genera (p. 201) "the majority of polyploid forms owe their origin to doubling processes in somatic tissue."

Müntzing (6) points out and insists that intraspecific chromosome races are undoubtedly ecologically different, and are to be found in different geographical locations. He believes that polyploids are, in the average, more hardy than diploids, and hence better adapted to a northern or alpine distribution. Rybin (8) and his co-workers found only the 48-chromosome potato in southern Chile. In case *S. tuberosum* is a true polyploid plant, having arisen either by autopolyploidy or allopolyploidy, and no 24-chromosome plants are known in the general region, is it to be assumed that the 48-chromosome S. *tuberosum* is introduced into the whole region? Theoretically this would be the case. However, the possibilities of finding 24-chromosome solanums within this region are not exhausted.

The Lands to Search

In Chile one should search for the varieties and strains of *S. tuberosum* and related plants south of Valdivia, along the coast and the coastal mountains to the Canal de Chacao, and south from the Lago de Ranco; along the foothills and Andean slopes to the upper reaches of the Estero de Reloncaví and inland to the Cerro de Tronador. The Isla de Chiloé merits a search in the interior and neglected parts, especially in the Montaña de Piuchue, although the opinion persists that the potato has been introduced into Chiloé, and the general evidence seems to bear this out. The potato has been collected from this region

before, but there has not been any thorough-going search in the fields and woods, persistent to the point of uncovering any freely-growing tuber-bearing solanums in stations where they may yet be regarded as indigenous.

What is to be said of Chiloé? It has long been thought of as the home of the potato. This may be true in one sense, but it is an adopted home. The top soils are thin and seldom rich in fertility. The modern plow turns up the sterile sand beneath too easily. The diseases so common elsewhere are only at the threshold of introduction here. There is a general absence of pathogens. If there were at one time some local diseases they have lost their destructive powers, and the well-known northern hemisphere diseases are appearing only in a minor way. The native potato insects are also few. Aphids are scarce and are obviously suppressed by the rain and wet. The general freedom from diseases may be due to a combination of environmental conditions, nutrition, physiology, and isolation. The provincial dialect possesses, according to Cavada (2), over a hundred words especially referring to the potato. But it must be remembered that since long before the Conquest, the Chiloté has lived there quietly, working hard for his existence, having a provincial language for his own agriculture, in which the potato played an important part. Of what significance is the place name *Cape Aitué,* indicating a "place of large and select potatoes?" Yet, if the potato is wholly indigenous it would be more generally found, possibly more in the nature of a weed. Until more convincing evidence is available one can only conclude that its ancestral home is not Chiloé, but elsewhere.

South of the Estero de Reloncaví the Chilean mainland narrows considerably, widening again much farther south in the region of the Territorio de Aysen. This mountainous region from the Reloncaví to approximately 45° South Latitude may harbor potatoes of value and promise. The nearest approach is from the canals and gulfs incising the mainland, which comprise, in effect, an inland sea. The interior can be reached by way of the many estuaries, and the steep-sided fjords and rivers which flow into them. The stations may be approached by way of the rivers Reñilhue, Yelcho, Palena, Cisnes, and Simpson and are located in the unsearched interior. An approach is feasible in some places from the Argentine side, as well as from the north on the Chilean mainland. The mountain slopes are covered with forests or other vegetation. The valleys are deeply cut, with a passage that is difficult and dangerous. The precipitous slopes, raging rivers, dripping forests, lack of roads, frequent rains, labor required to reclaim the land, and

the difficulties of grazing cattle leaves it today unexplored and practically untouched for any commercial use. Large areas still appear on the maps as "Inesplorado" and "Boscoso." The mountains are not tremendously high. The level of perpetual snow is often at 2000 meters or less. The favored growing levels would be below. The sharply cut ravines and precipitous slopes, dark forests, small mountain parks and meadows, and the latitude would provide many varying length-of-day situations, some of them highly advantageous for seed and tuber production. Somewhere within these areas may be the desired potato.

At present it is not possible to explore such a large expanse of territory. Progress would be slow at best, travel difficult, and existence tedious. A choice of selected stations, each reasonably well searched, might in a short time reveal the information needed for a further formulation of plans.

If the case for polyploidy has any merit and the 24-chromosome solanums are to be hunted, theory would indicate that they are outside the preferred range of the 48-chromosome plant. In that case they may be beyond the boundaries of Chile. If the diploids are less hardy they would be found farther north, beyond the generally accepted range of *S. tuberosum*. The 48-chromosome polyploid, because of demonstrated powers of adaptability to widely varying circumstances, may now have spread back over the region of the 24-chromosome diploid. If the 48-chromosome polyploid has acted solely as theory requires, it would be found in the colder, more difficult Andean environment. If the diploid parents exist there at all they may well be co-extensive with the polyploid progeny, contrary as it is to the idea of ecological incompatability. The Chilean mainland from Valparaiso and Santiago south to the Rio Imperial merits further examination, as well as the lands to be explored in the south.

What May Be Gained

Until the potatoes we seek are in our hands, no valid predictions can be made concerning their worth. If we can secure potatoes, transmitted by natural vegetative means, from the parental line they would be of great potential value in breeding. No variety of the potato breeds true to type from seed, and there is no reason to expect that seedlings derived from the parental strain will vary from this common habit. The natural environmental circumstances in some of the local wild communities may tend to diminish the chances of wide pollen distribution, retarding the multiplication of widely varying varieties, and keeping the successive generations in more nearly homozygous lines that are fertile.

The vegetative reproduction by means of the tuber is a device for keeping the line pure, and no variation would ordinarily be expected from this progression, except from bud sports which may arise. The value of the tubers, or of the seed, would lie wholly in the genes, whose potentialities are great. The greatest improvement made in potato breeding in recent years has come from plants of seedling origin. During the course of time some important factors may have disappeared, and at the same time valuable new genes may have been saved for introduction into the agricultural world. Desirable qualities arise in many hybrid strains, one of which may be increased vigor, of which there is great need, the increased vigor taking form as a greater capacity to resist diseases, to withstand light frosts or to recover from them, and improved ability to withstand the debilitating and predisposing effects of unseasonable weather and unnatural soils. The chief tools of the plant breeder are selection and hybridization, tools to shape the qualities and potentialities of the plant to demands of which some have not yet appeared. New diseases will afflict the potato, more insects may claim it as another host, new requirements of agriculture or industry may compel changes. There are recessive characters of value in the ancestry of plants and animals which remain unknown until some chance hybridization or recombination of genes causes them to appear. If there is potential improvements, it is carried in the genes.

Conclusion

Since the first appearance of the potato in Europe there have been difficult conditions for it to meet. As pointed out, its progress has been haphazard and indecisive. Radically changed environments, new plant pathogens and insects, and the increasing and varying human demands, have contributed toward larger improvements for survival and economical production. Although other species of tuber-bearing solanums are being studied and used in devising the wanted plants, the greatest success would seem to rest with the 48-chromosome *Solanum tuberosum* itself. For this purpose its native lands and secret dwelling places must be searched with diligence and attention. The value of the plant in world economy, the great savings and security to be effected by its improvement, and the foreshadowing demands of the future justify any effort toward a further search for the parental and other strains of the potato, and possibly the diploid parents themselves, if there are any.

The potato breeding work for the United States is in the hands of able geneticists who have well considered, long-range plans for the

improvement of the American potato (9). Until the sources of breeding stock have been thoroughly explored and the possibilities of improvement exhausted, no program of improvement will be complete. Chile alone may not yield the answer, but it offers a concrete, definite project of plant exploration and investigational work which can be concluded in a systematic manner.

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POTATO VIRUS DISEASES: REVIEW OF LITERATURE 1941[1]

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Sadasivan (21) conducted at Rothamsted protective inoculation studies with two pairs of related viruses. Tobacco and *Nicotiana glutinosa* plants were inoculated with tobacco mosaic virus or potato virus X^s (which causes necrotic local lesions in the test plants). When the tips of tobacco leaves were inoculated with either tobacco mosaic or X G virus and reinoculated with tomato aucuba mosaic or potato virus X^s, the results showed that the X G-inoculated areas were quite immune from X^s after 12 days, and the tobacco mosaic virus areas were immune from aucuba mosaic after 4 days. The bases of such leaves showed incomplete inhibition even after 20 and 24 days. When the bases of the leaves were inoculated, the results were essentially the same, but the leaf tips acquired resistance completely but much more slowly. When the X^s virus or the aucuba mosaic virus was mixed *in vitro* with healthy plant sap, or with sap containing an unrelated virus, its infectivity was reduced, but this inhibitory effect was much greater when the X^s virus or the aucuba mosaic virus was mixed with its respective related strain. It is concluded that in the plant tissues there is an intense competition among related viruses, and evidence was obtained that the degree of resistance to one is directly proportional to the amount of the other present.

Bawden and Pirie (5) secured experimental evidence that four viruses—tobacco mosaic, potato X, tomato bushy stunt, and tobacco necrosis—were irreversibly denatured by urea. For each virus there was a critical concentration of urea, below which no irreversible effect was exercised on infectivity. Inactivation of tobacco mosaic virus and potato virus X, but not that of the remaining two viruses, was accompanied by separation of the nucleic acid from the protein.

Bawden and Pirie (6) also conducted experiments to determine

[1]Pathologist.

[2]Not all papers included in this report were read in their original form; in many cases only the abstracts appearing in the *Review of Applied Mycology* were used.

the effects of alkali, sodium dodecyl sulphate, urethane, guanidine, pyridine, picoline, lutidine, aniline, nicotine, phenol, sodium salicylate, sodium benzoate, and sodium hippurate on the viruses of tobacco mosaic, tomato bushy stunt, and on potato virus X. The effect of alkali on tobacco mosaic is complex; treatment at pH 9.3 may cause increase of infectivity, a pH 10.5 loss of infectivity but not serological activity, and at pH 11 total loss of all characteristics. In the presence of alkali, sodium dodecyl sulphate readily destroyed the virus, separating the nucleic acid from the protein. Except nicotine and arginine, which formed with tobacco mosaic reversible fibrous precipitates, all the substances tested (at concentrations below 4 M) inactivated the viruses in neutral solutions.

Gulyás (11) found that the Y-virus in potato plants moves at the rate of 6 to 8 cm. in 3 to 4 days, the X-virus more rapidly, and the leaf curl covers 25 to 30 cm. in 8 to 12 days. An examination of fixed material revealed spherical X-bodies 3 to 25 Y in diameter, in various parts of Y- and crinkle-infected plants, a diseased cell usually containing one such element, though two or three were occasionally present. In certain infected cells, particularly those in proximity to X-bodies, or to vacuolated cells, 8 to 12 green granular bodies developed giving a plasmodium-like appearance. In such cells the chloroplasts turned dark yellow, or pale yellow-green, with a consequent disturbance of their normal functions.

Kohler (16) isolated three strains of the tobacco ring-spot virus from potatoes affected by a yellow spotting of the foliage, namely, (1) from a single plant of a stand comprising 50 plants of the Edelgard variety, designated "Ede;" (2) from a plant of a Pomeranian selection, "Po;" and (3) from several plants of the Frühmölle variety, "Früh." The type of spotting on the last-named variety was of a strikingly large pattern agreeing in all essentials with the North American calico, though obviously caused by a different virus. On the Edelgard and the Pomeranian plants the symptoms resembled those of aucuba mosaic. The effects of inoculating Turkish tobacco (Samson and Xanthia) with these three strains from potato were at first inconspicuous, but gradually acquired the intensity of a typical severe attack of ring rot. Only a few of the cucumber plants inoculated by rubbing with the three ring-spot strains developed systemic infection, though all reacted by the formation of pale green spots of the needle-prick type. The "Ede" and "Po" virus strains produced divergent symptoms on bean, *Phaseolus vulgaris*, leaves, those due to the former consisting merely of isolated sunken, necrotic spots, whereas the latter caused the formation of

numerous circular, reddish-brown, necrotic zones, followed by shedding of the inoculated leaves and in some cases by the brown discoloration of the stem and ultimate collapse of the plants. Extensive necrotic lesions, merging into chlorotic patches, and succeeded by a prominent yellow mosaic spotting, developed on inoculated *Nicotiana glutinosa* leaves. Pepper, *Capsicum annuum,* leaves reacted to the virus, especially to the "Po" strain, in an unusual and interesting manner; the delayed necrosis involving the petioles, leaf blades, and veins is apparently directly due to a toxin formed in response to the invasion of the stem apex by the virus. The thermal death point of the "Ede" and "Po" strains of the ring-spot virus was found to be 63° C. The "Früh" strain tended to be more heat-resistant. The two first-named strains were still infective at dilutions of 1:100, but not at 1:1,000, corresponding in this respect somewhat to Price's ring-spot virus strain. "Früh" strain caused some infection at 1 in 1,000. This corresponds to Price's strain No. 1. Inoculations with the "Früh" or "Po" strains were experimentally shown to protect Samson tobacco plants against subsequent infection by the "Ede" strain.

Offermann and Victoria (19) studied the serious potato disease presumably caused by Solanum virus 1 (potato virus X) which is liable to be confused with early blight, *Alternaria solani.* The dark, concentrically zonate foliar lesions are common to both. The symptoms of the virus, however, occur on the young tissues and are confined to the upper side of the leaves, whereas the fungus attacks the older leaves and involves both leaf surfaces, causing a severe necrosis of the veins. The virus also affects the stem and tubers, and produces a necrosis of the terminal buds and eyes. The virus causes symptoms on tomato very similar to those of spotted wilt. The two viruses may be distinguished by their reaction to mercuric chloride, which at a strength of 1 in 1,000 immediately inactivates the spotted-wilt virus, whereas potato virus X retains its virulence when in contact with the disinfectant for 5 days.

The virus was purified according to Bawden and Pirie's technique.

Valleau (28) made a comparative study of the host range and physical characters of the tobacco streak and potato yellow-dwarf viruses and indicates that they are similar, possibly merely strains of one virus. Tomato and potato, previously believed to be immune, were found to be hosts of tobacco streak. Potato yellow dwarf is known to affect red clover *Trifolium pratense,* and circumstantial evidence indicates that the streak virus is transmissible from sweet clover *Meliotus alba,* to tobacco. The symptoms produced by the two viruses are not iden-

tical either in tobacco or in *Nicotiana rustica*. In tobacco the yellow-dwarf virus causes vein-clearing and no streak. Tobacco with systemic yellow dwarf developed a combination of symptoms on inoculation by grafting with the streak virus. The author concludes that the fact that the streak virus does not afford protection against yellow dwarf does not necessarily point to a difference in identity.

Price and Black (20) carried out cross-protection tests in an attempt to clarify the relations between tobacco streak and the potato yellow-dwarf virus. Artificially infected *Nicotiana rustica* plants showing the systemic stage of tobacco streak failed to develop further symptoms of streak when inoculated with the severe strain of potato yellow-dwarf virus, with tobacco mosaic, tobacco necrosis, or with tobacco ring-spot; the plants in each case developed symptoms characteristic of the given virus. Of the plants systemically infected by yellow-dwarf, those inoculated with the severe strain of potato yellow-dwarf virus failed to develop further symptoms of yellow-dwarf, whereas those inoculated with tobacco streak or any of the other three viruses previously used, developed local lesions typical of the virus used as inoculum. These results indicate that plants affected with tobacco streak are not protected against potato yellow-dwarf virus, and it is concluded therefrom that the two viruses are not strains of the same virus, and in this sense are unrelated. Furthermore, the other viruses used do not seem to be related to each other.

Hansen (12) discusses the various systems of naming plant viruses. A list of the synonyms for the European potato viruses is given, as well as a collection of common synonyms for potato viruses. Most of the names for the diseases other than Danish refer not only to the clinical picture but also to the causal viruses. The Danish names, however, correspond only to the symptoms and are in no way connected with any of the causal viruses.

Hansen (13) discusses in detail the relationship between potato viruses and their ways of transmission. The writer does not believe that transmission of virus X can be explained by wind mutilation of leaves, and is inclined to believe that auto-infection plays an important part. A fully tabulated account of the experiments in Denmark is given, comprising infection experiments in the field in 40 different localities in 1938, 1939, and 1940. The dispersion of virus-Y infection within the individual plots was practically identical in the eastern and western parts of the country. There was an average of approximately 1.5 times more infection in the rows that were quite close to the Y rows than in those a row farther away. Shelter from the wind had a

rather marked effect on the amount of infection, but the effect varied with the other general conditions for infection. In special infection experiments with tobacco, as well as with potato plants, it was found that a considerable amount of infection took place about the middle of July in 1938. In 1939 the time for infection was somewhat later, and in 1940 it was still later. Much more virus infection was found in the immediate neighborhood of towns and of the coasts, and near marsh or other coast-meadows, than in corresponding areas at some distance from these localities. A high degree of positive correlation was found between the mean temperature in July and the infection percentage, but the line of regression was not straight. The above-mentioned factors influenced aphid population.

Black (7) in his studies on hereditary variation in the ability of the clover leaf hopper to transmit potato yellow-dwarf virus found that selective breeding through ten generations resulted in the development of two races of clover leaf hopper, *Aceratagallia sanguinolenta*, one active and the other inactive. Under conditions in which 80 per cent of the active individuals transmitted the potato yellow-dwarf virus, *Marmor vastans*, to crimson clover *Trifolium incarnatum*, only 2 per cent of the inactive insects and 30 per cent of the hybrids between the two races passed on the infective principle. Active individuals appeared in colonies of the inactive race, whereas, conversely, some inactive ones were present among the active. Active insects from an active race were more efficient vectors than those from an inactive race; a significantly higher percentage of males than of females transmitted the virus.

Black (8) found that leaf hoppers, *Agallia constricta*, collected in New Jersey carried a strain of the potato yellow-dwarf virus, *Marmor vastans*. This strain differs from the variety *vulgare* originally described from New York State and transmitted by another Agallian leaf hopper *Aceratagallia sanguinolenta*. The differences in the effects produced by the two viruses on crimson clover *Nicotiana rustica*, *N. glutinosa*, and *Solanum tuberosum* were minor but nevertheless consistent and easily recognizable. In two experiments the New Jersey virus protected *N. rustica* plants against the lethal variety of the New York virus. Because of the specific transmission of the New Jersey virus by a species of Agallia, it is proposed that it be named *Marmor vastans* H. var. *Agallia*, Nov. var.

Heinze and Profft (15) found that *Myzus persicae* is the only one of the potato-inhabiting aphids which is of any practical importance as a vector of viruses in Germany, though *M. pseudosolani* may

occasionally be implicated in the transmission of leaf roll. Studies on the migration of potato aphids were conducted at Dahlem, Berlin, representing a locality where there is generally rapid spread of virus diseases, and at Dromburg, East Pomerania. The increase of the insects was found to be favored by periods of fair weather, especially during April, and from May to mid-July. High winds bring the aphids out of their winter quarters, and light, dry breezes promote their movement from plant to plant. The disastrous early infestation by *M. persicae* was less prevalent at the Pomeranian Station than in the Berlin district because of the relatively late appearance and dispersal of the aphids at the former site.

Because of the over-wintering habits of *M. persicae,* the writers recommend at least one dormant spraying of peach and apricot trees.

Heinze (14) cites official statistics in support of his statement concerning the rapid and widespread extension of peach and apricot cultivation during recent years in Germany, a development calculated, if allowed to proceed unchecked, to terminate the production of healthy stocks of seed potatoes, as the aphid *Myzus persicae,* which is responsible for the transmission of potato viruses, overwinters on these fruit trees. Störmer's warning (the Mitt. Landov., Berlin 904-906, 1937) that no naturally healthy potato-growing regions would be left in Germany within a few years, owing to the fact that the progress of degeneration from west to east failed to receive the necessary attention, may well be realized unless a drastic limitation on peach and apricot growing is enforced, at any rate along the north German coast for a distance of approximately 150 km. inland.

Sandford and Clay, (23) report that during the last 10 years a potato disease apparently hitherto undescribed, and for which the name "purple dwarf" is suggested, has developed in many fields in southern, central, and north-central Alberta. It seems to affect all districts equally, but has not so far seriously reduced yield. The number of affected plants seldom exceeds 1 per cent and although infection has reached 5 per cent in a few cases, many fields appear to remain unaffected, although infection has reached 5 per cent in a few cases. All varieties seems to be susceptible.

Plants affected with purple dwarf are readily recognizable as they emerge from the affected seed pieces, being stunted, rigid, brittle, and frequently dark green. The sprouts may remain abortive and die. General stunting and distortion, with the early development of a purple color, especially on the margins of the apical leaves, are invariably present under field conditions. The underground parts are at first

apparently normal, but before long the older roots, then the stolons, and finally the epidermis of the lower stem turn brown and decay, discoloration starting at the extreme base of the stem and spreading outward through the roots and stolons and upward through the stem. The outer part of the brown roots and stolons may easily be slipped off. Tubers from affected plants are seldom over 1 inch in diameter, and, as a rule, only very few small ones or none develop. These tubers always show severe necrosis. The stolons and tubers give no secondary growth, and the old seed piece usually remains sound.

Under field conditions the pith of the stem is normal green to darker green in color, and remains sound until the disease is well advanced, when general disorganization may begin at the base of the stem. In the tuber and upper stem the pith usually remains normal. The phloem throughout the stems, stolons, and roots is discolored and often plugged with a material, that is stained deeply with Sudan III. A distinct browning of the outside of the vascular cylinder is a characteristic symptom in the lower stem, stolons, and roots. Experimental evidence and field observations strongly indicate that transmission occurs through affected tubers. The condition was transferred to the stems of healthy potato plants by inserting in them pieces of petioles from affected potato plants. Furthermore, the tissue of purple-dwarf plants yielded neither bacteria nor fungi. On this basis, the disease is considered to be of virus origin.

In addition to leaf roll, in potato samples from Silesia, Mark Brandenburg, Saxony, and Berlin; Kohler (17) found on examination at the Biological Institute, Dahlem, that some of these were infected by a virus transmissible by means of *Myzus persicae* and by grafting, but not by mechanical juice transfer. In the field the virus appears to be virtually latent, but in combination with other viruses, it causes severe crinkle, sometimes accompanied by stunting. In greenhouse plants the first symptoms of the disease are a pronounced upward rolling of the leaflets, similar to that found in leaf roll but usually only temporary. The leaves, moreover, remain soft and pliable and do not develop the chlorosis characteristic of leaf roll. In the Altgold and Wohltmann varieties the longitudinal growth of the shoots becomes accentuated, whereas in Altgold and Ackersegen the leaves are abnormally small. The foliage displays a faint, diffuse, yellowish-green tinge originating in the mild and lateral veins of the pinnae, and imparting to the entire plant a somewhat lighter aspect than that of normal stands. Anthocyanin spots are produced on the rolled leaves of Parnassia and Wohltmann. As severe crinkle is a typical sympton of

the virus in mixed infections, the designation K (Kräusel) is proposed for it.

Bald and Norris (1) studied the effect of the latent virus (virus X) on yields of potatoes. After stating that almost every plant of the six most commonly grown potato varieties in Australia appear to carry at least one strain of potato virus X, the authors describe an experiment carried out in 1939-'40 to determine the effect of the presence of this virus on yield. The seed tubers used were of the President and Factor (Up-to-Date) varieties. The latter were derived from a single tuber which some years previously had been found free from virus X. Before planting, the clean and infected tubers were indexed by inoculating from each to pepper, *Capsicum annuum* plants. These tests confirmed the presence or absence of the virus and demonstrated that the isolates were of average severity. The experiment was arranged so that the unit sub-plot consisted of three plants. Four sub-plots (President with and without, and Factor with and without virus X) were randomized in a group along a row, similar rows occurring four times in each of five long rows. Between adjacent sub-plots single clean President or Factor plants were set to reduce current-season infection between adjacent affected and healthy plants.

During the season no symptoms of virus X were noted on any plant, and no differences in vigor or growth habit were observed between healthy and affected plants of the same variety. In all, 182 plants grew, of which 90 were Factor and 92 were President. The mean yield per plant was 142 and 172 grams, respectively, for infected and clean President, and 148 and 240 grams, respectively, for infected and clean Factor. Thus the mean loss in yield resulting from infection was 30 per cent. The authors concluded that these results support the opinion that virus X is one of the main causes of the reduction in yield of potatoes in Australia. However, as the effects of the virus are spread evenly over the crop, they escape notice.

Bald, Norris, and Dickson (2) studied a disease of Factor potatoes in New South Wales that was diagnosed as spindle tuber. Three stages in tuber growth were differentiated by means of logarithmic curves based on measurements for sound and infected plants, and the following characteristics were noted in the diseased tubers: (1) The rudimentary tubers formed from the stolon tips are of abnormal shape, but smaller than those produced by healthy plants; (2) growth is uniform in all dimensions, from approximately 0.75 to 2.5 cm. in length, causing less expansion in this second stage than occurs in normal material; and (3) following a transitional period between the second and

third stages, growth appears to follow a comparatively normal course, but as apical growth begins in the diseased tubers, these are narrower in cross-section than sound ones of the same length. An analysis of the measurements made on Green Mountain tubers by Schultz and Folsom and on Bliss Triumph by Werner gave results similar to those obtained from Factor potatoes.

Scott (24) carried on investigations to obtain statistical information of the effect of the various types of mosaic disease, leaf roll, and wilting upon the yield of potatoes in Scotland. Slight mottle, usually caused by mild strains of virus X, but sometimes due to virus A, may reduce the yield by 16 to 25 per cent. Mild mosaic, generally caused by virus X, but occasionally by Virus A in combination with virus X, may reduce the yield by 30 to 40 per cent. Severe mosaic caused by virus Y alone or in combination with A or X may reduce the yield by 75 to 90 per cent. Severe mosaic increases two- to threefold, and leaf roll fourfold from year to year. Methods of controlling the mosaic group comprise the use of varieties virtually immune from viruses A and Z, the planting of the highest grade seed, adequate isolation, and thorough roguing, especially in the early part of the season.

Bald and Norris (3) state that it may be assumed that more than 90 per cent of the potatoes grown in Australia are infected by virus X. The losses from virus X appear to be at least as heavy as those from all other diseases combined. A virus-free Up-to-Date tuber was found. This tuber has been grown and the yield tested for freedom from virus X. The progeny of this tuber is being propagated to develop a possible virus-free stock to replace the infected stocks grown at present.

In a report on agricultural features of the Australian potato industry Bald (4) states in the section on potato diseases that losses caused by diseases (excluding latent mosaic) in Australia approach or exceed 20 per cent of the potential yield. The following conservative estimates have been made for percentages of losses incurred through preventable virus diseases (comprising all except latent mosaic) in the most widely grown varieties: Carman, 31 per cent; Brownell, 26; Up-to-date, 18; Snowflake, 4; Delaware, 6; Bismarck, 8; and miscellaneous, 7.

Schultz, Clark, and Stevenson (26) have shown that on the basis of symptomatology the reactions of potato seedling varieties to virus X may be classified as (a) symptomless carriers, (b) necrotic, (c) light green and slightly rugose, and (d) faintly mottled. On the basis of resistance to virus X, the varieties may be grouped as (a) immune

(b) rarely infected, and (c) easily infected. The corresponding reactions to virus A may be expressed on a basis of symptoms as (a) necrotic, (b) pale green and rugose, and (c) mottled; whereas on the basis of resistance to virus A, the varieties are grouped in the classes used for virus X. The resistance reaction of the parents to virus A or X is transmitted to a light percentage of the progeny of crosses, es pecially in the case of two resistant parents. Earlaine, Katahdin, and S. 24642 are immune from virus A by aphid infection but susceptible to it by grafting. These varieties apparently segregate for resistance and susceptibility to virus A in crosses with non-resistant varieties. Progenies of virus-X-immune X virus-A-immune have been developed that combine immunity from both viruses and should play an important part in the control of mild mosaic, of which these viruses are components.

Loughnane (18) describes two experiments conducted in Eire in 1937 and 1938 in which healthy tubers of different varieties were grown near a field in which cabbage had been planted and were exposed to natural infestation by *Myzus persicae.* The results obtained showed that the most susceptible of the varieties tested for leaf roll were Arran Cairn, Up-to-Date, and Arran Signet; intermediate in susceptibility were Arran Pilot, British Queen, Kern's Pink, Gladstone, Arran Peak, Arran Victory, Dunbar Yeoman, Ulster Monarch, May Queen, President, Great Scot, Arran Crest, Epicure, Redskin, and Dunbar Standard; and least affected were Flourball, Arran Bonner, and Majestic. Yield was reduced by at least 80 per cent in King Edward, President, May Queen, Arran Crest, Arran Pilot, Arran Signet, Redskin, and Dunbar Yeoman; between 50 and 80 per cent in Epicure, Arran Cairn, Dunbar, Standard, Ulster Monarch, Arran Banner, Eclipse, Gladstone, Arran Peak, British Queen, Kerr's Pink, and Arran Victory; and by 50 per cent or less in Up-to-Date, Great Scot, Majestic, and Flourball.

The evidence demonstrated that the effect of disease on yield is directly proportional to the effect on vigor. On the whole all the early varieties showed a serious reduction of yield when attacked; in main-crop varieties there was wide variation in the effects on vigor and yield, but a serious loss of yield followed extreme reduction of vigor.

In the 2 years of the test initial infestation by *M. persicae* took place on the 12th of May, and maximum infestation about mid-June. It was found that even when vectors and sources of leaf roll are present in a potato crop in rather large numbers, there is a significant dif-

ference in the extent of the spread of the disease to healthy plants growing at varying distances from the source of infection; healthy plants in proximity to the source are more likely to become infected than those removed from it by a distance of one or two rows.

Samuel (22) reports that certificates issued by the Ministry of Agriculture and Fisheries after inspection of growing crops of potatoes in England and Wales now take into consideration the health, as well as the purity, of the crops, which have to comply with two conditions: (1) The seed planted must be class 1, and (2) the crop must be grown at least 50 yards away from any other potatoes not eligible for entry under the first condition. These conditions are intended to assure that the stock is of good standard of health and that it was grown in some degree of isolation from outside sources of infection. It is emphasized that the aim of the English scheme is to indicate those stocks that are likely to have maintained their health to a satisfactory extent during their first year of growth for seed production. The author briefly summarizes the chief factors affecting the health of seed potatoes in England and discusses the spread of virus diseases within the field and spread into a field from outside sources. A good example of the latter was observed in Kent in 1938 when leaf roll spread from one corner of a field; the source of infection was possibly an adjacent cabbage field that had been cleaned up soon after the potatoes had been planted. Similar spread of leafdrop streak (potato virus Y) has also been observed. He considers it advisable not to plant potatoes adjacent to an overwintered Brassica crop. The destruction of the potato tops before the time of natural dying tends to produce more healthy seed, but it reduces the yield.

The Department of Agriculture for Scotland (9) has issued a register divided into four parts which shows in alphabetical order (1) the varieties, (2) the counties where grown, and (3) the growers of the crops.

Part I (T.S.(A)), seed true to type, immune from wart, and (N.I.(A)), seed true to type but not immune from wart, include crops that were inspected during the growing season and certified by the Department to attain a standard of purity of not less than 99.5 per cent and to contain not more than 1 per cent virus diseases, including not more than 0.5 per cent in all of leaf roll, severe mosaic, and wilding (witches' broom).

Part II (T.S.(H)), seed true to type, immune from wart, and Part IV (N.I.(H)), seed true to type but not immune from wart, include crops that were inspected and certified to be true to type, to

attain a standard of purity of not less than 99.5 per cent, and to contain not more than 3 per cent of leaf roll, severe mosaic, and wilding.

All crops included in the Register are the subject of a certificate to the effect that wart disease has not been known to have occurred on the land in which they were grown.

Another register (10), a supplement to the register of potato crops inspected and certified "T.S.(A)", "T.S.(H)", "N.I.(A)", and "N.I.(H)" during 1941, shows in alphabetical order the varieties and growers of crops that were found to be 99.95 per cent pure and true to type and to contain not more than 0.25 per cent of virus diseases and wilding, including not more than four plants per acre leaf roll, severe mosaic, and wilding.

Tamargo (27) reports that after 3 years' observations at the Agricultural Experiment Station, Santiago de las Vegas, Cuba, most of the potato seedlings and varieties introduced for trial purposes tended to lose their native vigor in their new environment on account of climatic influences (short days) and virus diseases. Some resistance to mosaic was shown by Alma, Hindenburg, Oldenwälder, Blaue, and Weltwunder, whereas Duke of York, Gloria, Hetman, and Jubel were highly susceptible.

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"STEM END BROWNING" AND "NET NECROSIS" IN POTATOES

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There is not the least doubt, that whatever is the true significance of these two well-known and widely prevalent troubles, their presence in potato tubers has caused serious consternation to the producer, shipper, purchaser and last, but not least, to the inspector both of table and seed stocks.

Whatever claims have been advanced that the more insignificant types of both these annoying troubles may be completely disregarded is analogous "to fiction rising pleasing to the eye." I believe all concerned will readily agree on one point *viz.*, that of preference of potatoes, whether intended for the table or seed, which do not exhibit these blemishes.

From the technical point of view most plant pathologists realize that these popular terms cover a multitude of most perplexing pathological as well as physical causes, all of which, or many of which, are indistinguishable by mere visual examination. No person should assume the responsibility from such cursory examinaton of deciding which of the types is harmless and which is not—if there are such types. None of them has a place in certified seed and certainly all are displeasing to the consumer.

The situation is most annoying simply because we cannot yet effectively and immediately eliminate these troubles as we can others, that more readily respond to known methods of control. To the producer, shipper and purchaser the question of the technical causes of the disease phenomenon is definitely less interesting than it is to the research worker. Research eventually will reveal most of the causes and thus lead to control or prevention—that is the sole aim of research—*viz.*, to have facts and information available which will enable the grower to raise a crop of potatoes that will not be condemned by an inspector as unsuitable for seed or table purposes after he has taken the trouble to produce it.

In some localities this stem end browning or net necrosis situation

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has become a really alarming problem, in others it has not yet become quite so evident, but may do so any time. To whom is the producer to look for assistance? To the plant pathologists? The plant pathologists throughout the world have studied these phenomena for some time and from all angles, and yet are scarcely farther ahead than their medical colleagues who may not know the cause and cure of many human ills, but who know much about reasonable prophylactic (preventive) measures and general methods of sanitation that certainly have shown appreciable beneficial results.

There is a suspicion in my mind that the present situation is the result of having failed to recognize the true significance of stem end browning and net necrosis possibly many years ago when the amount was definitely negligible and thus was passed by. Many of these troubles are definitely cumulative and, apparently, neglecting the earliest and most insignificant manifestations, together with the apologetic attitude of leniency on the part of inspectors clamored for by the shippers—and so welcome to the unfortunate grower—are partly responsible for the present situation.

Many a farmer has been advised to plant potatoes showing stem end discolorations. They may have been told that when early frosts kill the tops, the tubers may show stem end browning which will not in any way impair the vigor of the seed. Although they might have been fortunate enough not to encounter any trouble when using their own seed, is there any one who can distinguish one type of discoloration from another after the seed has changed hands?

What is to be done about it? Unless something effective is done and that without delay, these two troubles will continue and have most undesirable effects on potato production especially of certified seed. So much so that a formerly thriving and fairly lucrative business will pass into the hands of those prepared to do everything even at a great sacrifice. The ideal solution of the situation may not be practical at this stage but here it is: If the former well established and well founded reputation of potato growers is to be regained in the shortest possible space—my advice is not to plant a single potato that shows the least evidence of stem end browning or net necrosis under any circumstances. Where this is economically impossible at the present time, all responsible growers should at least plant a certain area with such scrupulously selected seed and continue to do so until he has eliminated all of these troubles. To wait until the research men have found a better solution is just postponing the issue. Research investigators are at work on the problems and if a more speedy solution is offered so much

the better. Meanwhile the speed and extent to which the suggested method is effected will shorten or lengthen the period it requires to eliminate these annoying troubles. At present there exists no safer methods and none more effective.

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